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CONTENTS.

APPENDIX.

NOTES ON THE

PROGRESS OF THE HOME AND FOREIGN IRON AND STEEL INDUSTRIES.

SECTION II.—1889.

IRON ORES.

I.—OCCURRENCE AND COMPOSITION.

II.—IRON ORE MINING.

III.—METALLURGICAL PREPARATION.

REFRACTORY MATERIALS.

FUEL.

I.—CALORIFIC VALUE.

II.—COAL.

III.—COKE.

IV.—LIQUID FUEL.

V.—NATURAL GAS.

VI.—ARTIFICIAL GAS.

VII.—COAL MINING.

VIII.—COAL WASHING.

PRODUCTION OF PIG IRON.

I.—BLAST FURNACE PRACTICE.

PRODUCTION OF STEEL.

I.—THE OPEN-HEARTH PROCESS.

II.—THE BESSEMER PROCESS.

FURTHER TREATMENT OF IRON AND STEEL.

PHYSICAL PROPERTIES.

CHEMICAL PROPERTIES.

CHEMICAL ANALYSIS.

I.—ANALYSIS OF IRON AND STEEL.

II.—ANALYSIS OF IRON ORES AND SLAG.

III.—FUEL ANALYSIS.

STATISTICS.

I.—UNITED KINGDOM.

II.—AUSTRIA-HUNGARY.

III.—BELGIUM.

IV.—CHINA.

V.—FRANCE.

VI.—GERMANY.

VII.—ITALY.

VIII.—JAPAN.

IX.—NATAL.

X.—NORWAY.

XI.—RUSSIA.

XII.—SPAIN.

XIII.—UNITED STATES.

BIBLIOGRAPHY.

LIST OF PLATES.

JOURNAL No. II.—1889.

PROCEEDINGS

OF THE

IRON AND STEEL INSTITUTE.

PARIS MEETING, 1889.

TUESDAY, SEPTEMBER 24TH.

THE AUTUMN MEETING of the INSTITUTE was opened this forenoon at the hall of the *Société d'Encouragement pour l'Industrie Nationale*, Rue de Rennes, Paris.

RECEPTION OF THE INSTITUTE.

M. GUSTAV EIFFEL (President of the *Société des Ingénieurs Civils*) expressed the great delight that the French engineers had in receiving their English brethren. They desired to give them a hearty welcome, for they owed their friends a debt, knowing full well with what courtesy the French engineers were received in England. They regarded English engineers with sympathy as their educators and masters in metallurgy, and they desired to show by the heartiness of their reception the esteem with which they regarded them.

M. HATON DE LA GOUPILLIÈRE (President of the *Société d'Encouragement pour l'Industrie Nationale*) also joined in the welcome to the members of the Institute. As a mining engineer, he desired to say how much the Iron and Steel Institute excited their sympathy, and he congratulated the meeting on the relations which existed between the engineers of the two countries.

Sir JAMES KITSON, President of the Institute, then took the chair, and said he desired to express to M. Eiffel, a gentleman who had made an European reputation by his magnificent work of construction in that city, and also to M. Goupillière, the thanks of the meeting for the kind reception which had been given to them. They were aware of the extensive preparations which French hospitality had made ready for them. They were always glad to visit their *beau Paris*, to see its beautiful monuments and its intelligent people. They were always delighted to view the fertile plains of *La Belle France*. They had a vivid remembrance of the graceful hospitalities which were dispensed to them in 1878, and they knew that on the present occasion their great engineers and ironmasters had freely opened their works and the examination of their processes to the members of the English iron trade. On behalf of the Institute, he desired to thank them for their kindness, with a vivid sense of all the favours and the graceful courtesy which they were to receive during the present week.

The minutes of the previous general meeting were then read, confirmed, and signed by the President.

THE SPECIAL BESSEMER GOLD MEDAL FOR 1889.

The PRESIDENT said he had to make an announcement with reference to the presentation of the Bessemer Gold Medal. At a recent meeting in London, the Council resolved to present M. Henri Schneider with a special Bessemer Medal for services rendered to the iron and steel trades of France. It was M. Schneider's intention to have been present to receive the medal, but in consequence of engagements at Le Creusot he was unable to attend. It was, therefore, proposed that the Medal should be presented to him on the occasion of the visit of the members to Le Creusot on Friday. It had, however, become necessary to modify their arrangements. He (the President) had arranged to go with another party to visit the Loire, and he would have the honour of being accompanied by M. Eiffel, who was kind enough to say that he would conduct that deputation. Sir Lowthian Bell had been good enough to accede to the request of the Council that he should head the party proceeding to Le Creusot, and he would formally present the Bessemer medal to M. Schneider

The basic steel made in France last year was probably one-fourth to one-fifth of the total make.

At the end of this month the make of basic steel will have reached 10,000,000 tons.

There were also made last year 600,000 tons of slag, containing about 36 per cent. of phosphate of lime, most of which was simply ground very fine, and used as a fertiliser without any other treatment.

We do not forget the valuable contributions made to the discussions at our meeting in Paris by M. Tresca; and in view of the advent of the general use of the forging press, M. Tresca's researches into the laws which rule the flow of solids are worthy of special technical study by those who direct the use of this new mode of working steel.

When I addressed you in May, I alluded to the subject of alloys of iron and steel, which, I remarked, are destined to play a more and more important part in industry. I call your attention to this subject again for the purpose of recording that this line of research has received much attention from French metallurgists, at the International Congress on Mining and Metallurgy, and a very interesting and exhaustive report has been presented by M. Gautier, a member of our Institute, on alloys of iron and steel.

The alloys of iron and chromium have been investigated and reported upon by M. Brustlein. Valuable and systematic research has been made into the processes of tempering and annealing by M. Osmond, and the use of metallic baths for the tempering of large masses has been dealt with by M. Evrard.

I hope the Council may be able to give a *résumé* of these papers in the *Journal* of the Institute.

The enormous development of the use of steel castings in the period which has elapsed since our last visit to France is one of the features of the day, and it is undoubted that at the Terre Noire Works, when the researches of M. Gautier, M. Euverte, and others gave that establishment a distinct pre-eminence as makers of steel castings, a lead was given which has been followed in Great Britain and elsewhere.

I have said but little in the few observations I am permitted by the limited time at my disposal, but enough, I think, to prove

Horsfield, Samuel .... Newton, N.B.
Hunt, Charles .... Birmingham.
James, Charles Henry .... Merthyr Tydvil.
Jaques, William Henry .... Bethlehem, Pa., U.S.A.
Jopling, Thomas .... Cleveland, U.S.A.
Jordan, Albert Edward .... Birmingham.
Jowitt, Charles Albert Renny .... Sheffield.
Kitson, Albert Ernest .... Leeds.
Korten, Rudolph .... South Bank, Yorkshire.
Lee, Henry .... Prestwich.
Lopes, George .... London.
Marshall, Francis Carr .... Newcastle-on-Tyne.
M'Murty, George Gibson .... Pittsburg, U.S.A.
Muller, Thomas Neil .... Middlesbrough.
Naylor, John William .... Leeds.
Otis, Charles Augustus .... Cleveland, Ohio, U.S.A.
Owen, David .... Morriston.
Parkes, John Israel .... Smethwick.
Pearce, Sir William George, Bart. .... Wemyss Bay, N.B.
Pochin, Henry D. .... Eglwysbach.
Preston, Fredk. Walter .... Kettering.
Reimers, E. .... Magdeburg, Germany.
Ridgely, William Barrett .... Springfield, Illinois, U.S.A.
Roe, Pearce .... London.
Rummens, Francis William .... Shirley.
Sampson, Richard H. .... Pontardulais.
Sauvée, Albert .... London.
Siddell, George .... Pitsmoor.
Slater, James .... Walsall.
Smith, Henry John .... Newmains, N.B.
Smith, Samuel .... Wednesbury.
Thomas, John Glyn .... Llangennech.
Thompson, Philip .... Middlesbrough.
Triponé, Emile .... Paris.
Twynam, Thomas .... London.
Tylden-Wright, Charles .... Dudley.
Walker, William Rose .... Chicago, U.S.A.
Western, Charles Robert .... London.
White, Maunsel .... Bethlehem, Pa., U.S.A.
White, William Henry .... London.
Widdop, Isaac .... Mexbrough.
Williams, Peter .... Wrexham.
Wilson, Lieut.-Col. G. H. .... Bala.
Wood, Edward .... Manchester.

Retiring Members of Council.

The General Secretary announced that the following Vice-Presidents and members of Council retired at the present meeting in accordance with Rule X.), namely:—

Vice-Presidents.

Mr. Wm. Evans. Mr. E. P. Martin.
Mr. Wm. Jenkins.

Members of Council.

Mr. G. J. Barker. Mr. Alfred Hewlett.
Mr. W. T. Crawshay. Mr. J. Riley.
Mr. G. J. Snelus.

The following paper was then read:—

NOTES ON THE IRON AND STEEL MANUFACTURE IN FRANCE IN 1887,*

AND AS ILLUSTRATED BY THE FRENCH EXHIBITS AT PARIS.

By PROFESSOR S. JORDAN, Paris.

The author presented to the Paris meeting of the Institute in 1878 a paper entitled "Notes on the Resources of the Iron Manufacture in France," and tried thereby to give his English colleagues a summary idea of the French siderurgy at that time. That paper dealt especially with the fuels, iron ores, and blast furnaces of France. In this new paper, prepared for the second Paris meeting, the author intends to complete his former notes, and to bring forward the changes which have occurred during the last ten years. He will be obliged sometimes, for the sake of brevity, to refer to the 1878 paper.

Section I.—Coal and Coke.

In his former paper the author has indicated the production of the French collieries, and especially the output of the six principal coalfields. He will now give, with some more details, the output for 1887, and compare it with the output for 1877, according to the official statistics.

* 1887 is the last year returned in the official statistics.

suit this special industry of bye-products so well as the English or German coals.

Section II.—The Pig Iron Manufacture.

According to the official statistics, the comparison of the pig iron production in France for the years 1877 and 1887 is as follows:—

	1877.	1887.
Pig Iron Production—	Tonnes.	Tonnes.
Coke pigs	1,372,000	1,547,000
Charcoal pigs	80,000	12,000
Coke and charcoal pigs	54,000	9,000
Sum total . .	1,506,000	1,568,000
Number of Furnaces in Blast—		
Coke blast furnaces	133	84
Charcoal blast furnaces	69	12
Coke and charcoal mixed blast furnaces	30	5
Sum total . . .	232	101
Consumption of Raw Material—		
Coke	1,900,000	1,800,000
Wood charcoal	150,000	15,000
Iron ores	3,323,000	3,453,000
Indigenous ores	2,346,000	2,298,000
Algerian ores	330,000	48,000
Foreign ores	647,000	1,107,000

These figures indicate that important changes have taken place during the ten years that have elapsed since the 1878 Exhibition.

The production of *charcoal pig iron* has continuously decreased, and now shows only an unimportant tonnage. There were in 1887 only a few charcoal furnaces, viz., some of them in the south-west of France, making special grey pig for gun-making purposes; two only in the Franche-Comté district, producing the grey charcoal pig so highly reputed in bygone times for the charcoal refinery; one in the Alps (Isere), and one in the Western Pyrenees. These two latter are represented in the metallurgical gallery of the Champ de Mars, and are worth notice, if only for their now unique character.

The Brignoud blast furnace (Isere) is smelting alpine spathic ores, and produces the excellent charcoal pigs used in the

ırtuis Steelworks for the production of steel by charcoal ι refining.

ι Ria blast furnace (Western Pyrenees), belonging to Messrs. ıltzer & Co., is producing, with the manganiferous brown ites, and the spathic ores of the country, grey and white ıniferous pigs, used in the Unieux Steelworks for making celebrated products.

ɜ smelting of iron ores *with a mixture of coke and charcoal* local and temporary peculiarity, and this practice is dis-ring more and more, either because the blast furnace s, who, being unable to use coke only owing to the small-f their plant, mixed coke with charcoal in order to lessen ›st of production, have finally put their furnaces out of or because they have decided to build larger furnaces, and ɜ coke alone. In 1887, there were only very few blast es using mixed fuels, and they were located in the east of ə, in the part which the author called, in his 1878 paper, ıampagne district, and where the furnaces using only char-ave disappeared. It looks probable that the use of mixed ›xists no longer, and certainly nothing can be seen of it in ɛhibition.

› *production of pig iron by means of coke* is therefore now ıly important branch of the French pig iron trade. The ' reported to the Institute in 1878 as to the geographical ıution of the blast furnaces in France. The following ıent will show the changes since that time:—

Furnaces in blast.

Districts.	1877.	1887.
North and Pas-de-Calais district	16	12
Meurthe and Moselle district	32	31
Champagne district	59	14
Franche-Comté district	9	2
Central district	21	7
North-Western district	13	1
Perigord and Aveyron district	19	4
Pyrenees and Landes district	18	11
Loire and Rhone district	29	10
Alpine district	6	3
South-Eastern district	10	6
	232	101

The total number of blast furnaces has decreased more than one half, but the pig iron production has nevertheless increased. From about 6500 tons the mean annual make per furnace has increased to 15,500 tons, and, if the details were looked for, it would be found that the progress in this respect has occurred in the two first districts, and, above all, in the Meurthe and Moselle district, which, with less than a third part of the total number of the French furnaces, has produced more than one-half of the total annual make of pig iron.

Proceeding now to rapidly review the various pig-making districts, the author will indicate the changes that have occurred since 1878, and at the same time point to the corresponding exhibits. As to the iron ore resources, he is obliged to refer the reader to his 1878 paper.

North and Pas-de-Calais district.—In this district the blast furnaces are smelting almost entirely Bilbao hematites and Meurthe and Moselle oolitic ores.

The more recently built ironworks, those of Isbergues (Pas-de-Calais), whose exhibits are to be seen in the Metallurgical Gallery, produce only Bessemer iron with Bilbao ores. The mean daily make of the two blast furnaces at these works exceeds 225 tons.

The Denain blast furnaces, whose model is exhibited in the "Palais des Machines," are smelting the same ores, and producing the same quality of iron.

The Anzin and the Maubeuge Ironworks (Northern Ironworks annexe) produce forge and foundry pigs by smelting chiefly oolitic Moselle ores.

The older blast furnaces in the neighbourhood of Boulogne, which formerly smelted local ores mixed with imported ores, are now out of blast.

Meurthe and Moselle district.—This district, by far the most important as regards the make of pig iron, employs only oolitic ores, obtained from the large Eastern ironstone field, which extends from the vicinity of Nancy to Luxembourg, through German Lorraine.

The fuel used here is either French coke from the Northern coalfield, or Belgian or Westphalian coke.

The blast furnaces produce either foundry or forge pigs, and

The Pont à Mousson furnaces, which exhibit very beautiful drawings of their plant, including an important pipe foundry;

The Frouard furnaces, owned by the Montataire Company;

The Gorcy furnaces on the Belgian border;

The Villerupt furnaces, belonging to the Chatillon-Commentry Company;

The Micheville Ironworks, belonging to Messrs. Ferry, Curicque, and Co., which include two blast furnaces, yielding each daily eighty to ninety tons of foundry pig, or 120 tons of forge pig.

Below is the composition of the Micheville pig iron, which will give an idea of the general quality of the iron made in this district:—

	Foundry No. 3. Per cent.	White Forge. Per cent.
Graphite	2·50	...
Combined carbon	0·70	2·75
Silicon	2·40 to 2·75	0·30 to 0·60
Sulphur	0·02 to 0·05	0·25 to 0·50
Phosphorus	1·60 to 2·00	1·60 to 2·00

Some of these works are smelting Luxemburg ores of the same character as the oolitic ores of the Meurthe and Moselle.

Champagne district.— This district has lost much of its former importance as a pig iron producer. Its blast furnaces are smelting local ores, associated with more or less Meurthe and Moselle ores.

The Champagne Forges Company exhibit specimens of their Pont-Varin-Wassy ironstones, which are mixed for special purposes with Pont-Saint-Vincent oolitic ores and manganiferous ores, as well as specimens of the pigs produced and used for the basic Siemens-Martin process.

The other works are only represented by various iron castings, some of them for ornamental, and others for building purposes.

Franche-Comté district.—The two operative blast furnaces of this district have not exhibited anything.

Central district.—There are no longer any charcoal furnaces in this district, which is represented only by the coke furnaces of Montluçon-Ville (of the Commentry-Fourchambault Company), and by those of the two Montluçon-Saint-Jacques and Commentry Works (of the Chatillon-Commentry Company). These furnaces smelt the local pisolitic ores mixed with imported

mixed with some foreign ores, *pure pigs* made with the excellent Pyrenean and Algerian ores. The percentage of sulphur decreases from 0·48 per cent. in the white ordinary forge pigs to 0·02 per cent. in the grey pure pigs; the percentage of phosphorus from 0·27 per cent. in the ordinary, to 0·05 per cent. in the pure pigs.

The Firminy Company possess one coke blast furnace (about 7000 cubic feet capacity), which can yield daily 120 tons of ordinary pig, but which is more usually making superior pig, spiegeleisen, and silico-spiegels (with a silicon percentage exceeding 20 per cent., according to the exhibited figures). In this last mode of working, the daily yield decreases to 10 or 15 tons. The ores used come from Algiers and Spain.

The "Forges et Acieries de Saint Etienne" Company also own blast furnaces at Chasse (Isere), but exhibit no pig iron.

The Givors blast furnaces belonging to Messrs. de La Rochette et Cie. produce almost exclusively foundry pigs for castings.

The more important works of this district, Le Creusot, are not represented in the Exhibition, nor are the Terrenoire and Lavoulte ironworks.

Some of the ironworks in the Loire region are using, for the production of superior iron and steel with ordinary pig, a special refining process (*Rollet's process*). It consists in the melting of the pig with an extra-basic slag, obtained by means of fluorspar and limestone. This melting is effected in a basic-lined or water-jacketed cupola furnace, blown by hot blast. The pig iron is thus purified by the removal of the greater part of its sulphur, and of a certain portion of its phosphorus. The fined metal obtained is sometimes cheaper than the pure pig made with manganiferous foreign ores. The Rollet process is not formally exhibited, but its products can be seen among the exhibits of the Holtzer and Firminy Companies.

Alpine district.—This small district is represented by the only two blast furnaces that it now contains, the Brignoud charcoal furnace, already spoken of, and the Allevard coke furnace (A. Pinat & Co.), yielding daily 19 to 20 tons of superior pig (grey, white, mottled, and specular), by smelting the celebrated local spathose ores.

South-Eastern district.—Here the blast furnaces employ chiefly imported ores from Algeria, Spain, &c.

As to the *manufacture of wrought iron by converting pig iron in open-fires and using charcoal as fuel*, or as to the so-called *charcoal wrought iron*, nothing is to be learned in the Exhibition, this description of iron not being represented. However, a few charcoal open-fires are still working, especially in the Franche-Comté and the Berry provinces.

The so-called *natural steel*, obtained by the same mode of treatment of pig iron, or *charcoal natural steel*, can be seen among the exhibits of Mr. Alphonse Gourju (Bonpertuis Steelworks), and perhaps of Messrs. Gouvy & Company (Dieulouard Steelworks) in the Metallurgical Gallery, together with shear and double shear steel, made by piling and welding this natural steel. These descriptions of steel are almost solely used for manufacturing agricultural implements and edge tools by some antiquated ironworks, and the output is now very small.

Puddled steel is still manufactured in some steelworks of the Alpine district (the Allevard Works, for instance), and more particularly in the Loire district. Messrs. J. Holtzer & Co. exhibit so-called *natural steels* intended for cutlery, edge tools, agricultural implements, springs, &c., and obtained by puddling the charcoal pigs of their Ria furnace. The Saint Chamond Steelworks, and the Firminy Steelworks also exhibit puddled steel, as well as the Dieulouard Steelworks (Meurthe and Moselle), and the Saint Jacques de Montluçon Steelworks (Central district), belonging to the Chatillon-Commentry Company. We have, however, already seen that the annual output of puddled steel is now very small: this process is gradually disappearing, and, besides, it is rather difficult to draw a clear line of demarcation between puddled steels and superior fine-grained puddled irons.

As to *puddled iron*, the annual output is also gradually decreasing, owing to the gradual increase of the use, for structural and mechanical purposes, of soft cast steels, obtained in the converter or in the open-hearth. The author does not find much interesting matter to offer about this description of iron.

For a long time the French ironworks have been in the habit of methodically arranging in somewhat numerous numbers or classes (4, 5, 6, and even more) the different qualities of muck bars, so as to have merchant bars, plates, and sheets of the same classes. The lowest number was used for the iron rails, and

about 143,000 tons, the quantity of basic steel contained in the 324,900 tons above stated. The producing power of basic steel in the French steelworks, as well as of acid Bessemer steel, is, however, much greater than would be supposed from the above figures. Indeed, although the official statistics indicate that some twenty-eight converters were at work in 1887, this only represents about two-thirds of the actually existing converters, which will number from forty-two to forty-four. Some Bessemer steelworks have been entirely idle in 1887, such as those of Terrenoire, Givors, Saint Nazaire, and Pagny on the Meuse; while some others worked with only a part of their plant.

The Bessemer steel manufacture was first introduced in France at Messrs. Jackson & Co.'s works at Saint-Seurin-on-l'Isle, near Bordeaux, and afterwards at Messrs. Petin, Gaudet, & Co.'s works at Assailly (Loire). It was afterwards developed in various districts, especially in the Centre, at the Imphy and Montluçon Works; in the Loire district, at the Terrenoire, Creusot, Saint Etienne, and Givors Works; and in the Gard district, at the Besseges Ironworks. The pig iron used by these works was made with mixtures of local ores and ores imported from Algiers and Spain, these last being somewhat dear, owing to the sea and railway freights. Hence the new steelworks, established during the last ten or twelve years, have been located in the closer neighbourhood of seaports, such as the Denain Steelworks (the first built), the Isbergues, Saint Nazaire, Boucau, and Beaucaire Steelworks, the first four being intended for using Spanish, and the last for Algerian ores.

The *Isbergues* Steelworks (Pas-de-Calais), belonging to the Acieries of France Company, are provided with two 8-ton American type converters, and are supplied with pig iron from two large blast furnaces. They announce their annual steel-producing power as 100,000 tons. These works exhibit their raw materials and their steels, classed in five categories, according to their hardness and mechanical properties. They have hitherto produced all kinds of steel rails, steel girders, blooms, and billets.

The Adour forges or Boucau Steelworks, near Bayonne, belonging to the "Acieries de la Marine et des Chemins de fer" Company, having two converters, also exhibit a ground-plan of their works, their raw materials, and their products, accompanied by

These works are delivering to the trade blooms, billets, bars of every description, plates and rails, as also wire rods.

The North and East Steelworks, at Valenciennes, are also using basic pigs of the Meurthe and Moselle district, mixed sometimes with extra-phosphorus pigs, imported from Germany or from the North of England. They give the possible output of their two converters as 80,000 to 100,000 tons of basic steel annually. They sell rails, girders, bars, billets, and blooms, and their exhibits can be seen in the North of France special annexe.

The Stenay Iron and Steelworks, in the Meuse Department, are about the only works in France working their special process. They decarburise pig iron so as to obtain rolled or cast products into small (one ton or about) converters, according to the *Robert patented process.** Their exhibit includes numerous specimens of the products. Mr. G. Robert's converter shows in its horizontal cross-section the form of the letter D: the tuyeres, five or six in number, are horizontally situated nearer to the upper surface of the melted iron bath, in such a manner that the blast does not penetrate through the whole bath, but acts only on the superficial layer, communicating to it a gyratory motion, which brings every part of the bath successively in contact with the blast. Mr. Robert also, for certain stages of the process, slightly tilts the converter, so as to help this gradual conversion of the iron, and he declares that he can, with a much smaller or much cheaper plant than the ordinary Bessemer plant, produce at will hard, soft, and extra soft steels of superior quality, capable of being easily welded or run into moulds.

Mr. G. Robert exhibits numerous castings of great variety, some made with weldable steel. A Parisian foundry shop, with which Mr. Robert is also connected, produces steel castings obtained by his process, which he declares to have been introduced at some American and British works. Mr. Robert uses for his converter an acid or a basic lining, according to the material to be converted. So far as the author knows, the Stenay Works alone are just now working with small converters in France. Other processes, using also this class of apparatus, such as those of Messrs. Clapp and Griffiths, and others, have received trials in some French works, but the author cannot say what success they have obtained.

* See Mr. Garrison's paper on "The Robert-Bessemer Steel Process," p. 266.

The most general *mode of working* is the *scrap process*. The *ore process* is not employed in France as far as the author knows, and the combined use of scrap and ore, as in the *Landore process*, is only in current practice at the Allevard Works, as far as the author can say.

The *nature of the lining* varies in the different works, and according to the description of materials used. Sometimes the lining is *acid*, that is, it is made with sand, ganister, or silicious puddle; sometimes it is *basic*—that is, made with magnesia bricks or puddle (according to the system patented in 1869 by Mr. Emile Muller), or with dolomitic bricks and blocks; at other times the lining is *neutral*—that is, made with chrome ore (according to the *Valton-Remaury process*). When the lining is made with chrome ore, Messrs. Valton and Remaury state that no material is taken from the lining either by the molten metal or by the slag, so that no corrosion takes place, and it becomes possible to act on the metal either by scrap, or by ores, or by various agents, in such a manner as to effect a complete dephosphorisation, and to produce various descriptions of steel. Messrs. Valton and Remaury exhibit drawings of furnaces neutrally lined, specimens of their chrome ore and linings, and products of some steelworks working their process. French steelworks, such as Fourchambault and Alais, for instance, choose the neutral lining rather than the basic one, which, they say, is sooner worn out, and above all when some iron ore is used in the process.

The *dephosphorising mode of working*, properly so-called, that is, the conversion of truly phosphoric pigs (such as those of Meurthe and Moselle) into cast steel by the open-hearth process, is not yet much used in France. This description of pig iron is sooner dephosphorised in the basic Bessemer converter. Mr. Fould-Dupont, however, shows in his beautiful exhibit (Central Gallery) cast steel of many different forms obtained in open-hearth furnaces from his Pompey pig iron.

On the other hand, in many steelworks, the basic or neutral lining is used for making open-hearth steel with ordinary pig and scrap, not free enough from phosphorus to yield good steel on an acid lining, and too low in phosphorus to be worked in the basic converter. Some of them are even working pure pig and scrap upon basic and neutral hearths, and produce soft and extra soft steels

Some other steelworks, although of minor relative importance, have also interesting exhibits.

The Hennebont forges, in Brittany, show their extra soft steel, obtained on basic hearths and worked into sheets and tin plates, which they decorate in the finest style with pretty paintings, and which are used for making domestic and kitchen utensils, preserve boxes, &c.

The Montataire Works produce also open-hearth steel for sheets and tin plates.

The Valenciennes Steelworks exhibit tyres, axles, girders, and sundry bars made from Siemens-Martin steel.

The Ariége, Alais, Fourchambault, and Marnaval forges exhibit open-hearth steel of many different forms and sizes.

SECTION VI.—MANUFACTURE OF BLISTER STEEL, AND OF CRUCIBLE CAST STEEL.

The use of *cementation* or *converting-furnaces* is somewhat stationary in France. There were in 1877 thirty-four converting-furnaces with an output of 1717 tons of blister steel; in 1889 the number of working furnaces was twenty-four and the output was 1491 tons.

These furnaces are not employed only for the carbonising of superior wrought iron bars, intended for the making of shear-steel or tool cast steel; they are also used for adding carbon to certain puddled steels and even to certain cast steels for special purposes.

In reference to *crucible steel*, the official statistics give, for 1877, 101 furnaces with an output of 7252 tons; and for 1887 only 39 furnaces (containing 501 crucibles) have produced 7532 tons. The old furnaces, heated by coke fires, and containing two or four crucibles each, are now to be found in a few inconsiderable works; the large steelworks employ actually nearly everywhere large gas Siemens-furnaces, containing twenty, and even forty crucibles.

The melting of crucible steel is not only employed for producing tool cast steel by the fusion of blister steel, or for making homogeneous iron by the fusion of pig iron with malleable iron. This mode of melting metals has now taken a prominent place in the

steel castings, as well as their cast steel wires and piano-strings, are well worth attention.

The Chatillon-Commentry Company exhibit wolfram, chrome, and carbon crucible steels, and deliver to the trade very diversified products, from chrome steel plates and shells to piano-wires, as also very heavy steel castings.

Messrs. Marrel Brothers possess in their Rive-de-Gier Works an important crucible casting shop, and exhibit chrome steel shells, as well as their neighbours.

There are also some smaller works which have crucible casting shops for making tool steels, &c.

SECTION VII.—MISCELLANEA.

After having thus briefly reviewed the different branches of French siderurgy, the author, before concluding these notes, will add some information in reference to the plant of certain French ironworks and some points of manufacture.

Metallurgical plant.—Messrs. Marrel Brothers are just now erecting in their works a very heavy steam hammer of which they exhibit a reduced model, and give the principal dimensions as follows:—

Weight of the falling mass	100 tons
Weight of the anvil block	00 ,,
Maximum height of fall	6 metres
Steam cylinder diameter	2 ,,

This steam hammer will be used with two 180-ton steam cranes, and two others of 50 tons each. It is to be established in a large shed, in which a 50-ton steam hammer is already working, along with 100-ton cranes. Messrs. Marrel Brothers exhibit large forgings, as, for instance, big cranked wrought iron shafts for large steamships, which prove both the power of the plant and the skill of the workmanship.

The Saint Chamond Steelworks possess a 100-ton steam hammer, which is used for the working of large ingots (one of those exhibited weighs 100 tons), intended for manufacturing heavy steel guns.

The Creusot Works exhibited in 1878 a model of its 80-ton steam hammer. Messrs. Schneider & Co. have not gone beyond

specially established for the service of a group of 16 Gjers pits. This mill, as well as its engine (which was constructed by the Cockerill Company), is well worth the attention of the visitors, owing to its many interesting features.

The visitors can see in the Metallurgical Gallery steel wire rod hoops of very great length (some more than 3000 feet long), which testify to being rolled in special mills. Some ironworks, indeed, possess rolling mills of great producing power, designed on the German type. These mills are capable of rapidly drawing soft steel billets, six to seven centimetres square, into No. 20 to No. 22 rods ($\frac{44}{10}$ to $\frac{54}{10}$ millim. diam.) by means of one or two sets of roughing rolls, making 200 to 225 revolutions per minute, and of seven or eight sets of finishing rolls, making 450 to 500 revolutions per minute, the motive-power being transmitted by hemp-ropes from a strong steam-engine. This engine is generally a compound one, with two horizontal cylinders, 28 inches and 42 inches diameter, 40-inch stroke, making 80 to 100 revolutions per minute. The Fourchambault Forge (Commentry-Fourchambault Company), which exhibits a steel-wire rod hoop, No. 21, among others, 202 kilog. weight and 1383 metres long, employs also a special rolling mill of another system (the *Bedson system*, as employed by Messrs. Richard Johnson & Nephew, Manchester).

In reference to *furnaces*, the author would state that several gas-firing systems of Siemens and others are in practical use in France, as well for heating ingots, piles, blooms, slabs, &c., as for melting metals. The Gjers pits are only operated in a few works: the cause being, perhaps, the notable decrease in the steel-rail manufacture during the last two or three years.

The visitors can see in the "Palais des Machines" a collection of Piat's portable oscillating crucible furnaces, with and without a movable hopper. These furnaces are rather used for melting copper and bronze alloys than for iron and steel. Mr. Piat has patented and exhibits a new form of furnace, which he styles the *cupola-crucible*, and which is intended for the benefit of founders of iron and steel alloys who cannot employ ordinary cupolas for the making of small castings. A special lifting contrivance allows, by means of a small windlass and balanced levers, without crane use, of the furnace being lifted high enough to allow of pouring metal into the ladle.

these works there have been used, at the same time, chemical analysis, calorimetry, microscopy, and even electrical measures. Visitors to the Exhibition can see in the Metallurgical Gallery an apparatus used in the Montluçon-Saint-Jacques Steelworks for studies of that kind—the Evrard apparatus, for ascertaining and measuring metal dilatations at high temperatures. Alongside of this apparatus will be found the Mesuré and Nouel pyrometric telescope, employed for ascertaining the temperature of incandescent bodies, and based on polarisation phenomena.

These various scientific studies have had an influence which is considerable over the French metallurgical works, although the author cannot possibly do more than allude to it. One of their results, and perhaps not the least important, is the considerable increase in the making and employment of steel castings in France, a fact which has forcibly impressed visitors to the Exhibition of 1889.

Forging, tempering, and annealing steel, and especially steel in large pieces, have made important progress. Tempering is no more now, as in former times, a process aiming only at the hardening of steel owing to a somewhat mysterious property. It has been made sufficiently clear, owing to the studies of Messrs. Osmond and Werth, especially undertaken in order to enable practical metallurgists to turn to profit the molecular changes effected in cast metals by more or less sudden temperature changes, resulting from various new tempering processes, as, for instance, tempering in refrigerant mixtures (Schneider's patent) or in molten lead (Montluçon-Saint-Jacques patented process). It is not now always hardness, formerly generally associated with brittleness, which is required and obtained from tempering; it is sometimes quite the contrary—that is to say, body and malleability.

practical working of the process, might possibly have failed for want of the knowledge possessed by Mr. Riley. Then last, but not least, there was needed the application of considerable capital in order to bring the matter to a successful issue. Mr. Gilchrist and his late partner, Mr. Thomas, were fortunate in obtaining the assistance of Messrs. Bolckow, Vaughan, & Co., and the ready and valuable co-operation of Mr. Windsor Richards. Thus, however largely society might be indebted to M. Gruner for what he had done, undoubtedly, for the practical working of the system, the world was still more indebted to Mr. Snelus, Messrs. Thomas and Gilchrist, Mr. Riley, and, lastly, to the enterprise and perseverance of Messrs. Bolckow, Vaughan, & Co., for giving to the world a valuable contribution to metallurgical science. He expressed this opinion without wishing to detract in any way from the great service rendered in this direction by what had been done by one of the most scientific metallurgists of his day.

Mr. EDWARD RILEY said that Professor Williamson had proposed a basic lining at the meeting of the Institute at Swansea in 1870.

Sir LOWTHIAN BELL said that the date of Professor Gruner's exposition of the principle involved was 1867.

Professor JORDAN said, as it was a matter of history, he could not omit making a statement with regard to the basic process. The scientific ideas of Professor Gruner were first printed, he thought, in 1867. In 1869 a Parisian engineer made trials on a small scale with magnesian bricks, and two patents for dephosphorisation by means of basic linings in converters, or on the open-hearth, were taken out. He was about to have the linings tried at Le Creusot when the war began, but he was not able to find ironmasters disposed to carry it out; and, therefore, the basic process slept until Messrs. Thomas and Gilchrist discovered it some years afterwards. The experiments would perhaps have been made some eight years before if war had not broken out.

The PRESIDENT said, unless any other member desired to speak upon the paper, he would move that the best thanks of the

meeting be given to Professor Jordan for his communication. It had taken an immense amount of care and labour to prepare. It was a record of the progress of the iron and steel trades, and was historically a very valuable paper to be enrolled in the proceedings of their Institute. It was a paper which, he thought, would assist most materially in their examination of the products which were on view in the Exhibition, and would also instruct them, if they read it, as to what they ought to see in their excursions during the present week. They were deeply grateful to Professor Jordan. Some of them knew the immense amount of labour which he had devoted to the preparation of the paper, and he was sure that the members would accord to him their hearty thanks by acclamation.

A vote of thanks was then passed to Professor Jordan.

The PRESIDENT said the next paper to be read referred to the proposed Channel Bridge, and had been presented on behalf of Messrs. Schneider & Co. and M. Hersent. It was a matter of very great interest, and it was a great compliment to the Institute, that a project which had been so seriously studied as that had been should be presented to them. It foreshadowed the consumption of a million tons of iron and steel.

The following paper was then read by the Secretary :—

ON THE PROPOSED CHANNEL BRIDGE.

By Messrs. SCHNEIDER & Co., Creusot Iron Works, and H. HERSENT.

PART I.

I.—Introductory Notice.

The idea of connecting England with the Continent by a bridge is not new. It has from the beginning of this century occupied the minds of a great number of distinguished men, but the labours of M. Thomé de Gamond particularly contributed to render the idea popular.

Most of the schemes hitherto proposed have been insufficiently worked out.* They have all been found impossible to execute, and for this reason each has, in succession, sunk into oblivion.

A submarine tunnel was next thought of as a means of communication between France and England.

The advocates of the bridge, however, have once more given the subject their attention, and the object of the present paper is to show that the construction of a bridge between France and England may now be considered capable of realisation in practice. We may say that the problem is at present clearly placed before the technical authorities of both countries.

However gigantic the undertaking, the many and various improvements which have been made in the art of bridge-building fully warrant every hope of success in an attempt to build spans of metal, 500 metres in length, across the Channel, supported by columns resting at different depths on the bottom of the sea.

The metal it is proposed to use is steel. The extensive use that has lately been made of this metal, both in France and elsewhere, notably in the Forth Bridge, which is the outcome of the unmistakable progress of metallurgy, removes every doubt as to the feasibility of dispensing with about fifty per cent. in weight by the use of steel, without endangering the safety of the structure.

* The technical details and estimates have been worked out in conjunction with Messrs. Sir John Fowler and B. Baker, chief engineers of the Forth Bridge.

formed by a rough calculation at first sight, assuming that the arrangement of spans shown in the plan is adopted, permits the following estimate of cost to be given with reasonable certainty:—

Fr.380,000,000 for masonry supports, and Fr.480,000,000 for the metallic superstructure—in all, Fr.860,000,000, or £34,400,000.*

The works for the tunnel and the railways in both countries would have to be planned later on, in agreement with the companies whose lines would lead up to the bridge. The time required for the completion of the undertaking may be fixed at about ten years.

II.—GENERAL DESCRIPTION OF THE BRIDGE.

§ 1. Situation.

The situation which seems preferable for a bridge connecting England with the Continent is, as it were, suggested by Nature herself, namely, the line stretching over the shallowest parts of the Channel, and connecting the shores where they are closest to each other. This line commences at a point near to Cape Grisnez, and reaches the coast of England near Folkestone, passing over the banks of Colbart and Varne. The adoption of this line would enable the existence of these two banks to be taken advantage of, so as to avoid working in great depths, and thereby diminish the height of the piers to be erected.

The banks are situated near the centre of the Channel about six kilometres apart. The depth of the water at that point does not exceed seven or eight metres at low water, and they are separated from each other by a depression about 25 to 27 metres deep. Between the banks of the Varne and the British coast the depth does not exceed 29 metres, but between that of Colbart and the Cranaux-Oeufs the bottom sinks somewhat abruptly down to 40 metres; it then attains 55 metres about midway across, when it begins gradually to rise. In these parts, then, the chief difficulties would be encountered in laying the foundations.

The sketch submitted gives about the shortest distance available for the ready connection of the existing lines of railway in both countries, without difficulty or an unusual amount of work.

* Converting the franc at 10d.

to increase the surface of the base in contact with the surface of the ground.

The section of the piers will form a rectangle, 25 metres in length, and their width will have to be suited to each system of columns. This rectangle will terminate in semicircles, so as to oppose the least possible resistance to the currents.

Supposing 55 metres to be the length of the piers, the surface of the base of the piers in contact with the ground will be 1604 square metres. Where the depth is less, the surface will be proportionately smaller. Up to a certain height, the masonry will cover the whole surface of the base, while higher up two pockets will be provided in order to decrease the load upon the foundation, the sections of the walls being of sufficient strength to resist any additional loads. The masonry will be built inside metal caissons, similar to those used for ordinary bridge piers, and they will be sunk by the pneumatic process. These caissons, which will terminate in metal collars to secure the masonry, will be floated out to the spot where they are to be grounded. This will enable the ground to be carefully cleaned, and promote the application of the concrete that is to be interposed between the masonry and the bottom, as will be explained further on.

The caisson will, moreover, be surmounted by a movable dome, which will be removed when the upper part of the column is completed, so as to enable the masonry to be carefully finished with squared stones above the level of low water. Special arrangements will be made for anchoring the columns in the masonry, so that the anchorages may be at all times readily inspected in order to ascertain whether anything is out of order in each separate portion of the work. The whole of the piers will occupy a little over one-twelfth of the section of the Channel. This reduction of the section of the Channel is not likely to exercise a notable influence on the erosion of the bottom, or to bring about an appreciable increase of the speed of the flood and ebb tides. The distance between the piers, fixed at 500 and 300 metres for the large spans, will not be less than 200 and 100 metres respectively for the small ones, and will, at all events, be sufficient to prevent their proving an obstacle to the free navigation of sailing vessels. As regards steamships, no such danger is to be apprehended. The current, which

The system of girders to be employed is that of simple, unlatticed beams, so as to ensure the proper distribution of all stresses. The secondary beams provided are intended to reduce the length of certain members, to prevent buckling of tension members, and to give all members in compression proportions suitable to the lengths concerned, whereby it becomes possible to leave the co-efficient of compression, which would increase the weight, out of consideration.

The level of the permanent way is 72 metres above the low-water level. This height might have been reduced by arranging the permanent way in the lower portion of the bridge, but in that case it would have been necessary to make the cross-beams a great deal longer, and, consequently, heavier.

By raising the permanent way, on the contrary, as it is proposed here to do, a marked economy is attainable, which will certainly not be absorbed by any increased expense involved by the necessity of erecting viaducts at both ends of the bridge.

There will be a double set of rails, and the width of the flooring proper will be 8 metres.

The whole width of the bridge is variable. The greatest distance between the axes of the main girders is 25 metres, such a space being necessary to ensure the stability of the structure under the action of violent gusts of wind. The roadways are of the ordinary width of 1·50 metres between the rails. The latter will be set in grooves to obviate accidents. The floor, made of ribbed sheet iron, is to cover the bridge throughout its length, so as to make every part accessible to the men appointed for the supervision of the bridge. Between and outside the lines of rails, platforms are provided for the men to stand on, and thus keep out of the way of passing trains. Upon the flooring it will be possible to establish "refuges," stations for the guards, signal-boxes, switches, &c. All these arrangements may be multiplied according to the requirements of the traffic, and placed at any convenient points on the spans. On the piers, lighthouses may be erected, to indicate obstacles to be avoided. The various kinds of lights used in lighthouses may also serve to indicate to shippers the distance from the Colbart and the Varne banks. It would have been easy to establish a bridge with four lines of rails instead of two, but the probable development of the traffic did not appear to warrant any

These resistances offer every appearance of safety, alike as regards the ground, the ordinary masonry, the body of the pier, and the granite blocks supporting the metal columns. The base appears to be sufficient to resist the different transverse and longitudinal stresses (of which wind is the most important cause) that may tend to overturn the piers.

The length of the spans supported by the columns is 400 metres.

The surface exposed to the action of the wind on this distance is about 7590 square metres.

The surface exposed to the action of the wind on the metal columns, 622 square metres.

The surface exposed on the 20-metre sub-basement, 370 square metres.

The surface exposed on the lower part of the piers, 1570 square metres.

Assuming that the force of the wind, and the strength of the pressure exercised by the currents, attain altogether 270 kilos. per square metre, the stresses produced upon each of these surfaces will be as follows:—

$$\begin{aligned} 7{\cdot}590\text{m}^2 \times 270\text{k} &= 2{,}049{,}300 \text{ ks.} \\ 622\text{m}^2 \times 270\text{k} &= 167{,}940 \text{ ks.} \\ 370\text{m}^2 \times 270\text{k} &= 99{,}900 \text{ ks.} \\ 1{\cdot}570\text{m}^2 \times 270\text{k} &= 423{,}900 \text{ ks.} \end{aligned}$$

And the moments of overturn will be—

$$\begin{aligned} 2{,}049{,}300\text{k} \times 137{\cdot}1\text{m} &= 280{,}959{,}030 \text{ ks.} \\ 167{,}940\text{k} \times 95{\cdot}4\text{m} &= 16{,}021{,}476 \text{ ks.} \\ 99{,}900\text{k} \times 66\text{m} &= 6{,}593{,}400 \text{ ks.} \\ 423{,}900 \times 28\text{m} &= 11{,}869{,}200 \text{ ks.} \end{aligned}$$

Total moment of overturn at the base of the piers . . . 315,443,106

One length of span of 400 metres weighs	1,164,000 ks.
Two metal columns	2,010,000 ks.
One masonry pier	148,675,000 ks.
Total weight	151,849,000

The point of emergence of the resultant x from the centre of the pier is

$$x = \frac{315{,}443{,}106}{157{,}849{,}000} = 1{\cdot}99\text{m}.$$

at the junction of the structure with the ground. Each of these air locks will be provided with sluice valves arranged at the bottom, and with special devices for facilitating access and inspection, for removing excavated matter, and for filling up the excavations with concrete.

The first piers on each shore may be constructed without necessitating any alteration in the means ordinarily employed for this kind of structure. The experience acquired in sinking these first piers will thus enable improved methods to be adopted for the thorough clearance of the soil, the filling of the compartments, and, in short, the completion of the whole base in the case of depths exceeding 20 to 25 metres below the surface of the water. Hitherto foundations laid by the pneumatic process have scarcely ever exceeded 20 to 25 metres below the surface of the water. In exceptional cases they have reached 30 and above 35 metres, but at such depths accidents have sometimes occurred, which appear to have been the result of excessive fatigue on the part of the men employed, and of the want of proper provisions for arranging the air supply.

Divers going down in search of sponges and corals descend to a depth of 50 metres, and thus experience the effects of the compression and expansion which would be obtained in using compressed air at such a depth. It will not be too much, therefore, to say that the ground will be capable of being inspected under all the piers before the concrete is filled in at the base.

It may also be taken for granted that the bottom can be cleared beforehand by means of special apparatus, enabling compressed air to be dispensed with, and that the filling of the compartments and air chambers can be effected, either outside or inside the pillars, without its being necessary for the men to perform any important work below.

In considering the matter from this point of view, the question arises as to what would happen if the 120 cubic metres of concrete required for filling one compartment were conveyed down through a funnel pipe. It was found that if the water contained in the lower working chamber could be ejected to make room for the concrete, the filling of that chamber could be satisfactorily completed, and the concrete will in no way be inferior than in any of the other

The part of each caisson situated above the level of low water will be movable, and can be utilised successively for several piers, and it will consist of a sort of dome composed of metal plates suitably fitted together. These will cover the structure of the pier, and enable the lower ends to be sunk to the sea bottom in such a way that the masonry, although floating, can be completed as if it were erected on land. This has been successfully achieved in building the dry docks at Sargon and Missiessy, at Toulon, where 45,000 cubic metres of masonry, representing a weight of 100,000 tons, were kept afloat in the caissons for several months.

The piers, at a depth of 55 metres, would have to support the load of 12,000 tons at their juncture with the ground, which is by no means an unheard-of achievement.

Plans 3, 4, and 5 illustrate the general arrangement of the caissons; they show the lower portion, or concrete chamber, the central portion containing the ballast masonry, and the top or dome that is to surmount the whole.*

MASONRY.—The masonry of which the body of each pier is to consist should be set with good homogeneous calcareous materials from Marquise, Boulogne, &c., of which there is a great quantity in the neighbourhood of Gris-nez. The materials can be carried to the spot either from Ambleteuse, Boulogne, or Calais, and will cause no trouble.

The mortar required for the whole structure should consist of Portland cement, in the proportion of 500 kilogrammes per cubic metre of silicious or granitic sand. Calcareous or schistose sand must be avoided, as liable to decomposition. Upon the floor of the caissons a layer of concrete 1·50 to 2 metres thick is to be formed to protect the iron stiffening beams, and above that the ordinary masonry shall be laid of rough quarry stones, which shall rise up to the low-water level, two pockets being left which will render the structure lighter, and will greatly facilitate the work on the lower portion, when it is required to fill the chambers. At each successive height of about 4 metres, two courses of dressed stones will be placed, which will have the effect of better distributing the load, and rendering the tendency to settle down more uniform. The level surface of the lower portion below the low-water level *should also* consist of rough stones. From the low-water level

* *These plans may be consulted at the Offices of the Institute.—ED.*

be 700 metres long and 350 metres wide, so as to admit of the plant necessary for the simultaneous construction of a number of girders. The bottom would be utilised for constructing the foundation of the caissons. Several docks would have to be provided in the port at half-tide level or somewhat lower, which would be isolated from each other, and separated from the sea by floating dams, after the manner of floating docks, that would have to be operated whenever the caisson is taken out, so as to simplify this operation as much as possible. Besides the port, a tidal dock would have to be constructed, with quays, bridges, and all necessary arrangements for facilitating the embarking of men and goods, and for ensuring the safety of the floating stock. The northern railway lines would have to lead up to the quays, and to any other points that may be deemed desirable, so as to enable all the material and machinery to be carried from place to place by railway, and in order to facilitating the loading, unloading, and the storage of same.

The dwellings of the workmen should be established near at hand, but it is very probable that the steam-ship traffic would permit of the employment of workmen residing in Calais or Boulogne, especially at the works to be performed in the offing. It is, moreover, very likely that important quantities of material would have to be conveyed by these ports. This division of labour on the French coast would benefit the whole of the operations, and prevent obstruction at any point of the district occupied by the works. On the coast of England, the port of Folkestone and others would be made use of for similar purposes. A network of telephonic cables should connect the different loading stations between them, and also with the yards on land and in the offing, so as to ensure that unity of action which is absolutely necessary in the execution of great undertakings such as this. The first portion of the foundation caissons, which includes the lower chambers, and the cross-beams up to a height of 3·50 metres to 4 metres, will be constructed in a closed basin, as has been done with the caissons built in Toulon, Antwerp, and Saigun. They will be afloated by opening the doors at the spring-tide, so that they may be brought up to the outer harbour, where the work will be continued.

In the outer harbour the erection of the metal walls and the

If, after inspection, it should be found that the place where they ground is not the right one, the piers will have to be raised, and the whole process gone through over again, until the column is in its proper place. In fact, the method to be adopted is very similar to that which we used with M. Castor for putting in place the piers of the Arles bridge over the Rhone.

At a distance of from 200 to 300 metres from one another, strong anchors would be run out attached by chains to a number of barges supporting and raising them. These barges will be connected with the caisson of the pier by sufficiently strong lashings to enable it to be retained in its place, to line it out, and to determine the distances, all of them operations requiring the attendance of very experienced engineers, capable of duly taking into account the deviations due to the action of the tides. The putting into line and fixing of the distances may be effected when the bottom of the caisson is at a short distance from the ground (say from ·50 to 1 metre). It will thus be possible to admit into the chambers in the lower portion of the masonry an amount of water that will give the caissons sufficient weight to enable them to touch the ground, and to insure stability, which would make it more easy to ascertain whether they are placed in the right position, and are perfectly vertical.

Whenever it might be found that a pier was not in its proper position, it would be necessary, in order to get it afloat again, to remove the water, to fill the air locks with compressed air, and to begin the same operation afresh. If, on the contrary, the operation proved successful, it will be sufficient, in order to ensure the stability of the caisson, to add to the load a certain amount of masonry, and to withdraw the water or compressed air which had been used during the provisional loading, preliminary to placing the pier in position.

The position of a pier sunk in the midst of anchored barges, and attached by the necessary moorings, would be very similar to that of a spider in the middle of its web.

By reason of the particular position which each pier would take up, it would probably be necessary to strengthen some of the moorings, and to run out several more anchors.

The barges used for that purpose will have to be provided with

weighing 80 to 20 tons, employed in foundation caissons. The mounting and taking to pieces of this dome will be effected by means of a floating derrick, capable of lifting a weight of from 40 to 50 tons.

The lower part of the dome will be furnished with a gallery, or horizontal platform, which will be used at the same time for the purpose of increasing the general stability. In the middle part there will be another platform or gallery, above high-water mark, for receiving the cranes necessary for lifting the materials required for the masonry, after the caisson has been finally placed in position.

Levelling the Ground.—Before the caissons are put in place, it will be easy to ascertain, by preliminary boring, the nature of the ground upon which the pier would have to rest, and to see whether it is perfectly horizontal or not. These experiments will also permit of making sure that the ground has sufficient resistance to sustain the piers, or whether it is necessary to prepare a special bed for them. Such levelling of the bed will probably be requisite in the case of piers near the coast, but owing to the small depth of the sea in those parts, the pneumatic process may be used without any difficulty. For depths of from 20 to 35 metres, which hitherto have only been obtained in exceptional cases, no uneasiness need be felt with regard to the applicability of compressed air, inasmuch as experience will show the practical improvements that may be made in the methods and means already employed.

About twenty-four piers will have to be erected in portions of the ground lying at a depth exceeding 35 metres. For these twenty-four piers, the experience previously acquired cannot fail to prove a safe guide as to the improvements that may be made in the methods of operation, and to give practical value to works which hitherto have only been attempted in cases of exceptional difficulty.

Should it so happen that, in levelling the ground for the piers that are to descend to the maximum depth, any danger need be apprehended from the use of compressed air, there will be no necessity, nevertheless, to remain inactive, for owing to its special structure the ground can be acted upon by means of rotating machinery that can be set in motion from the platform, or it may

thus to prevent the water from entering the shaft during the operation. In operating in this manner, and in the case of each of the compartments of the lower part of the caisson, it will beyond doubt be found that the foundation leaves nothing to be desired in respect of strength, since the same operation will be carried out for each separate part. In fact, the whole of the work will consist in repeating partial operations such as these, for which, therefore, suitable machinery will have to be provided, and it may be considered certain that the normal pressure exercised by the concrete remaining in the shafts will be sufficient for the removal of the slime and grout. The test of such practical data as are available in this kind of work justifies the choice of this mode of operation. The only objection that occurs to the mind is, that it is unlikely for 120 cubic metres of concrete to be got ready in the space of from fifteen to twenty minutes. It does not appear impossible, however, to obtain such a supply, nor even difficult, seeing the enormous quantity of concrete that will be required, and the very powerful machinery that must necessarily be employed. Each pier, when immersed and placed on the ground, will have, for a depth of 55 metres below the low-water level, the following data :—

Displacement of water (at low water)	70·513m³
" " (at high ")	75·970m³
Difference of tide	5·460m³
Volume of the pier	86·000m³
Volume of pockets	28·800m³
Volume of masonry	57·200T
Weight of masonry	1·160T
" caissons	148·870
Load sustained by the ground	150·030
Surface of piers at the base	1·604m²
Load expressed in kilogrammes per square centimetre . .	9·3k
Weight of metal columns	2·010T
" flooring	7·164T
Total load supported by the ground	157·850
Total load expressed in kilogrammes per square centimetre .	9·8k

UPPER LEVELLING.—Whenever a pier is fitted in position, it becomes necessary to raise the masonry from the lower water-level up to the base of the metal part, that is, a distance of 20 metres, and up to a height of 15 metres above the highest water-

Taking for granted that the works will be sufficiently protected against the action of the tops of the breakers, and that it will even be possible to shelter them against the less powerful action of the swell, the undulations of which cannot cover more than 100 metres distance from the top of one wave to that of another, or measure more than 2·50 metres from top to bottom, it may be inferred that, in the case of a pier 57 metres long, such a pier will not be thrown out of the perpendicular by any rocking motion to which it may be subjected, and which will only represent a fraction of that sometimes experienced by ships situated near the pier. Piers sunk deep into the water, and forming a considerable bulk, will only undergo part of the effects consequent upon the surface being thrown out of the level, and will present, as already mentioned (even while afloat), the appearance of small islands in regard to the ships that may approach them, while the vessels carrying materials will in most cases follow the undulations of the surface of the sea. The work here contemplated has a certain analogy to the erection of a number of isolated lighthouses upon rocks, which have always caused a considerable expenditure of labour and capital. These works, difficult as they were, did great honour to the able and skilled engineers who devoted themselves to successfully carrying them out, but it is plain that an immense amount of trouble and labour would have been saved had these structures been built upon a metal caisson placed upon the bottom of the sea, in the season when that was practicable. The lighthouse in the estuary of the Oder may be mentioned as an instance illustrating this statement, resting, as it does, upon a metal caisson.

§ 3.—Materials and Machinery required for the Completion of the Works.

The usefulness of a special port for the construction of the caisson, the fitting of the girders, and the sailing and floating plant has been sufficiently dealt with above. Such ports, as before stated, would have to be situated as nearly as possible to the point at which the works are begun upon either coast.

Each of these ports would have to answer the immediate and

IV.—CUBING, ESTIMATES, AND TIME REQUIRED FOR COMPLETION OF WORKS.

The following table shows in a condensed form the relative importance, and the number, of the piers to be constructed, such construction requiring about four million cubic metres of masonry and about seventy-six thousand tons of metal.

Statement showing the Work Necessary in the Construction of the Piers.

Piers under Low Water.	Masonry.			Caissons.	
	Breadth of Piers.	Cubic Metres per Pier.	Total in Cubic Metres.	Weight of Caisson.	Total Weight.
Metres.	Metres.			Tons.	
5	14	17,300	242,200	311.00	
10	6	20,500	123,000	396,30	
15	8	24,500	196,000	466,80	
20	18	28,600	504,000	561,60	
25	30	31.900	957,000	618,60	
30	16	37,600	601,600	697,00	
35	2	40.500	81,000	790.20	
40	6	43,400	[illegible]	873,80	
45	4	48,000	192,000	966,40	
50	[illegible]	52,600	210,400	1,058,200	
55	10	57,200	572,000	1,163,200	11,163,200
Totals.	118		3,939,600		76,309,800

If it be desired to complete the whole of the works within a period of ten years, which does not seem at all impossible, about two years would have to be devoted to preparatory works for establishing working yards and buildings, so that the whole time, with this preparatory period included, would extend over twelve years. In such a case the foundation-work would have to be completed one year before the superstructure is begun, but it might be commenced even a little before the first year has quite elapsed. Thus ten years may be considered as the limit necessary for the foundation-works and the superstructure.

The labour would have to be divided between two working yards situated on either coast, so that each yard would have to turn out two million cubic metres of masonry, concrete, and caissons,

Details of Construction of Caissons.

Average Column with Base at 30 Metres below the Low-water Level.	Quantities.	Time.
		Days.
Construction of caissons	697,000k	60
Loading same before moving	2,200m²	10
Conveying same to place of sinking . . .		2
Masonry to be erected before sinking . . .	17,500m³	175
Clearing the ground (?) under the edge . . .		30
Fitting in place and final clearing of ground . .		20
Application of concrete	2,400m³	20
Time lost through bad weather and holidays .		160
		477

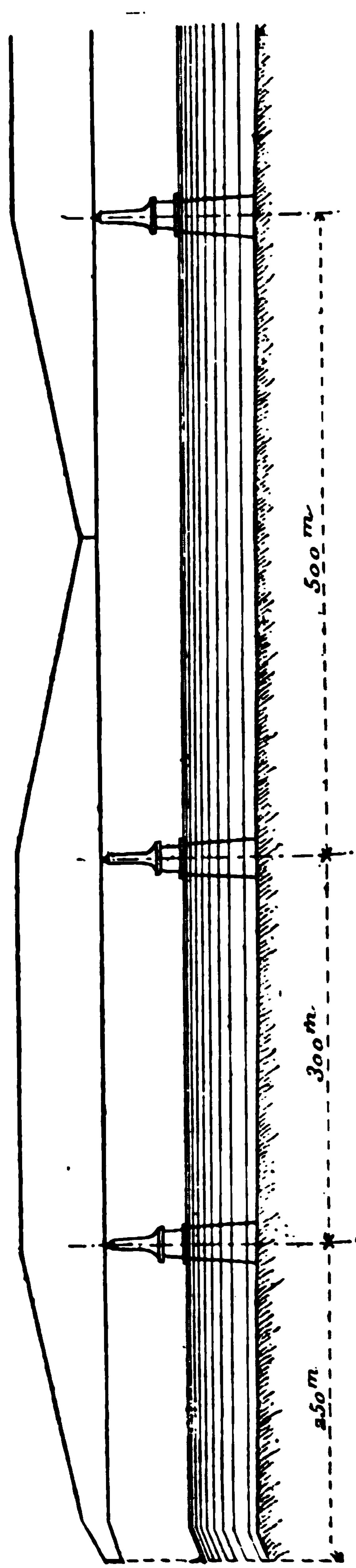
The supply of the immense quantity of materials necessary does not appear to offer any very great difficulties. As regards the concrete, and the rough bricks and stones, the chalk quarries situated near Marquise may easily be taken advantage of, and they will probaby suffice to supply all that is required in this respect.

The shipping of such materials may be divided among the ports of Calais, Boulogne, and Ambleteuse proportionately to the facilities which each of those ports offers. The unloading on the spot where the work is carried on will be effected by labourers, with special machinery, and no complications are to be feared in this connection, except such as may arise from the unsatisfactory condition of the sea, which may be guarded against in the manner indicated in the preceding chapter.

The sand required for making the mortar will be supplied by the beach.

Cement is manufactured in considerable quantities all around Boulogne, from whence 50,000 tons per annum can be easily obtained. The granite for the capping of the piers may be derived from the quarries of Chausey, Flamanville, &c., situated on the coast, and placed beforehand in a condition suitable for the purpose.

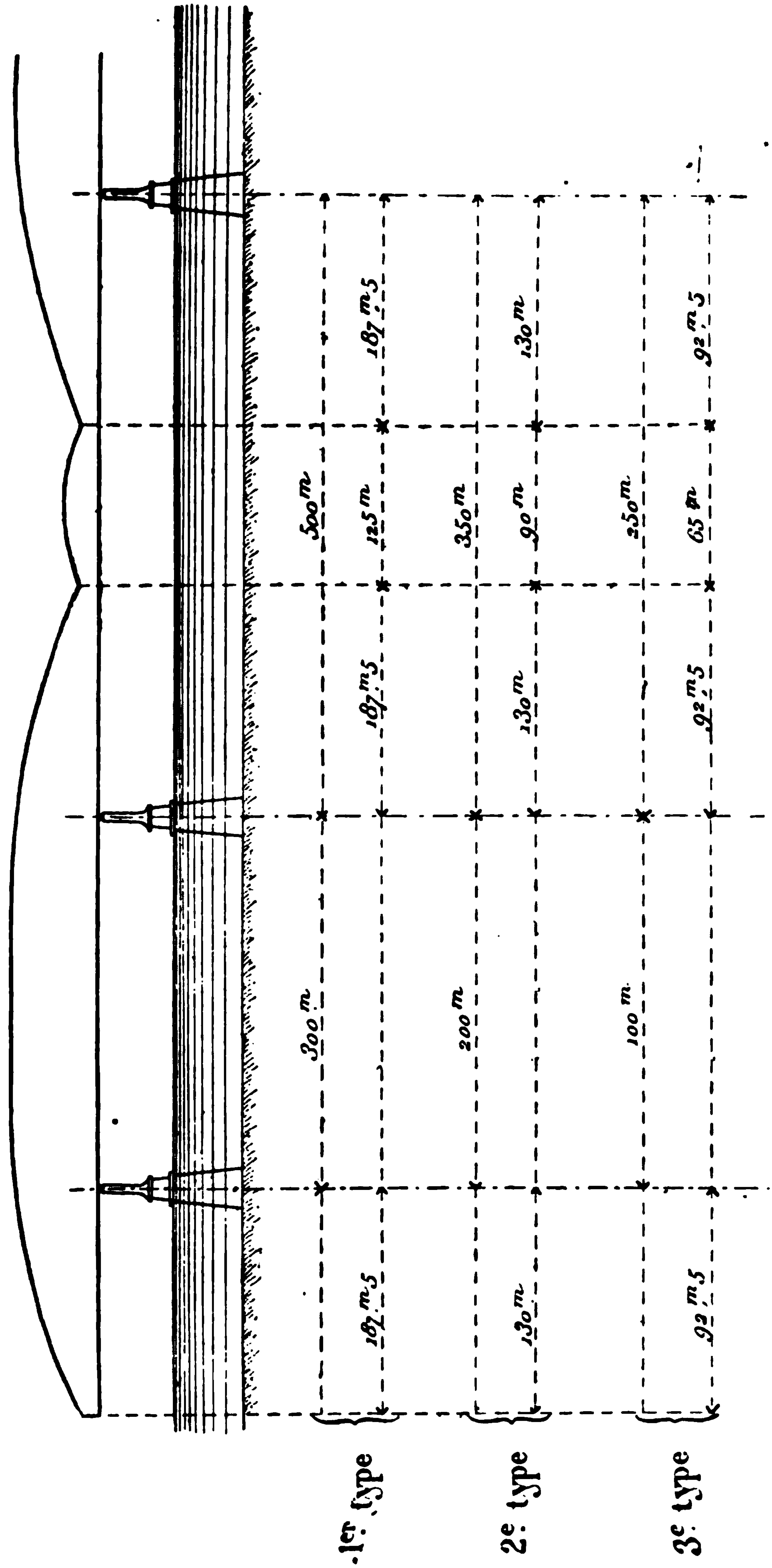
whole length of 300 metres, and extending on either side in the form of cantilevers of 250 metres, so that the junction of two cantilevers should constitute a span of 500 metres in all. The accompanying sketch shows this arrangement.



It is a well-known fact that in the Forth Bridge the two large spans are not completely covered by the cantilevers, the latter being connected by an ordinary central girder.

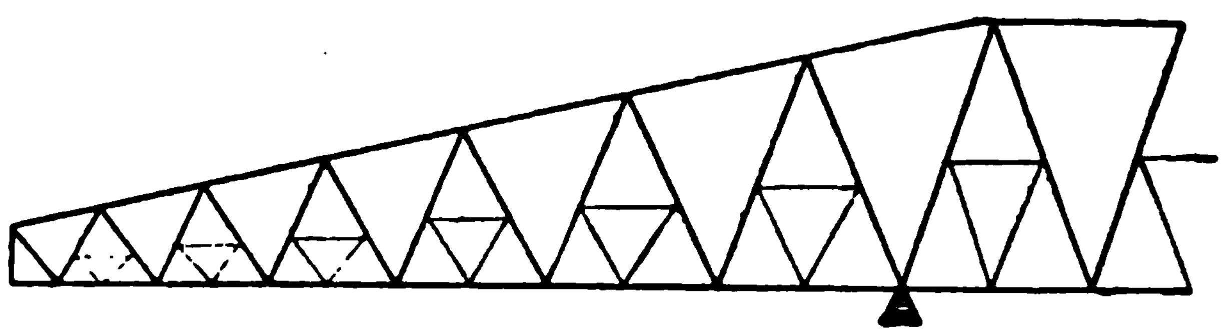
It therefore becomes necessary to ascertain whether the addition of such a central girder would result in diminishing the weight. The nature of this paper does not enable us here to reproduce the calculations to which this inquiry has conducted us, but it may be stated that these calculations have shown that the addition of a central girder is advisable, and that, supposing the distance between the points of support to be 500 metres, the space comprised between one-third and one-fourth of the distance between the points of support is the best indication of the length to be given to the same, for by this means a saving of about 17 per cent. is realised on each of the cantilevers. The sketch on p. 69 shows the arrangements adopted for the three types of spans.

It now remains to determine what arrangement is to be adopted with *regard to* the main girders of the

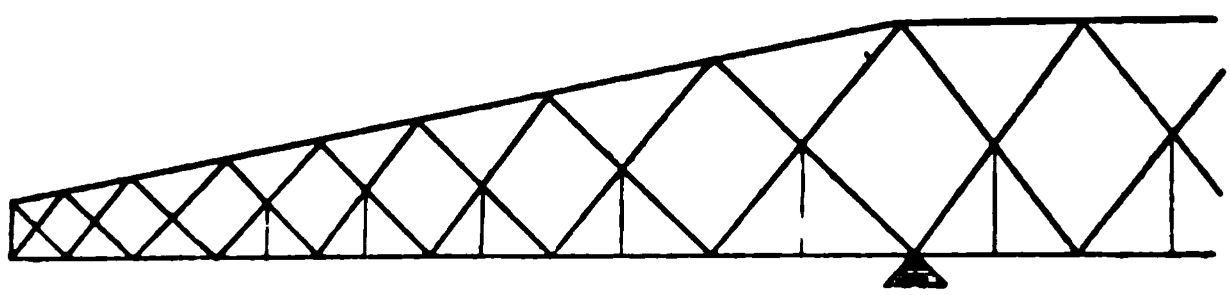

187m5
300m
187m5
500m
125m
187m5
130m
200m
130m
350m
90m
130m
100m
250m
92m5
65m
92m5
1er type
2e type
3e type

bridge. The best girder will be the one that will necessitate the employment of least weight while offering sufficient resistance to vertical loads and presenting the least surface to the wind.

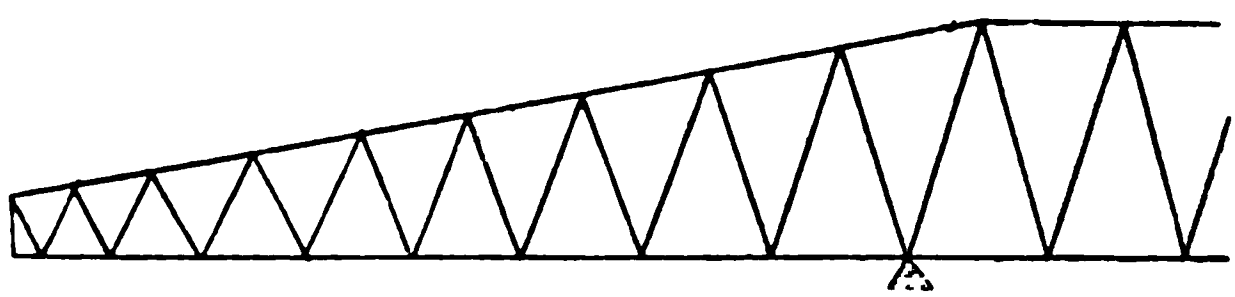
Many types of girders of the same height, and presenting about the same intervals between the lower apices, have been examined, it being desirable to avoid taking into consideration the weight of the beams and of the sleepers under the rails.



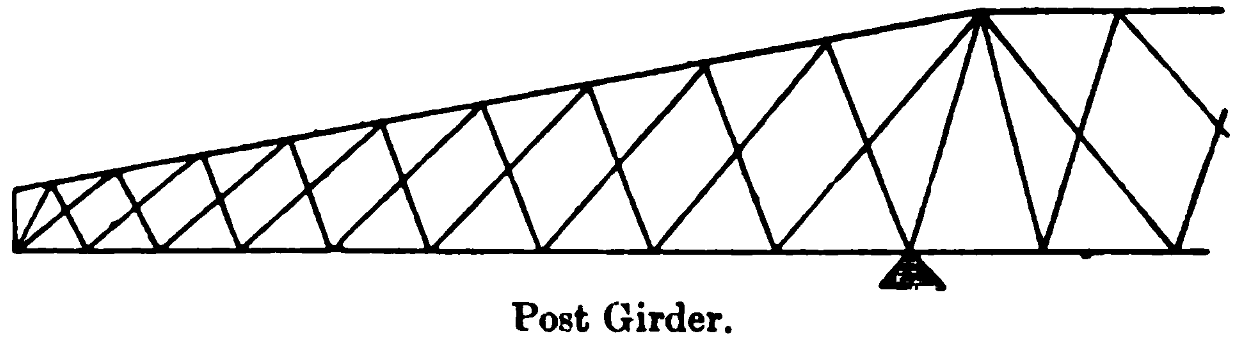
Warren Laced Girder.



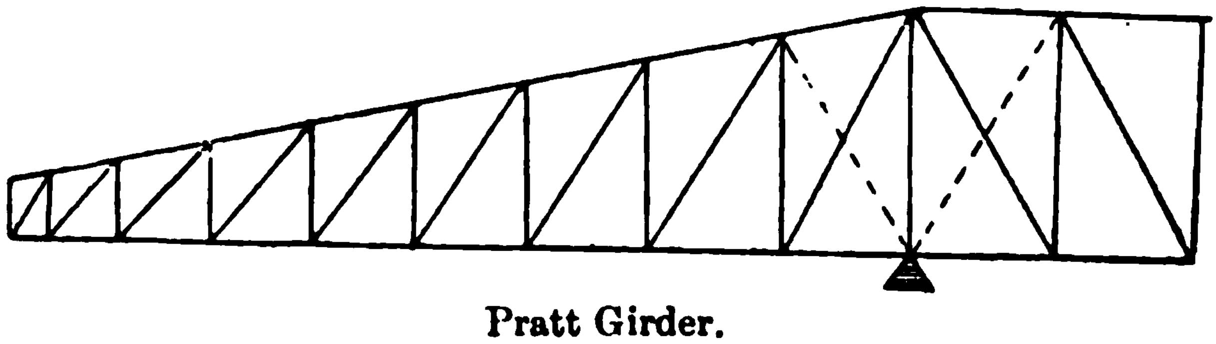
Warren Compound Girder.



Warren Simple Girder.



Post Girder.



Pratt Girder.

and 65 metres high almost throughout the span of 300 metres. Each girder consists of a top and bottom member connected by latticed girders forming isosceles triangles. The lower members of the two girders have a distance of 25 metres between their axes in the central span of 300 metres, and an interval of 10 metres at the ends. They are horizontal in the central span, but are raised to a height of 5 metres at the ends of the cantilevers. The upper members are connected in the largest portion of the central span, but diverge at a certain point, so as to be 10 metres apart at the ends, and this is also the case with the lower members; in the cantilevers they assume the shape of polygons inscribed in a circle of 650 metres radius.

All the principal members of each girder, as well as the latticed girders, are formed of plate and section iron divided into four segments. The inclined members are of simple sections.

The lower members are square in section. They are 2 metres across in the central span, but decrease in height towards the ends of the cantilevers down to 1 metre. The tip members have the same width as the lower ones, but as the segments of which they are composed are longer, their section varies between 3 metres and 1·50, and their size is variable, according to the open length. The distance between the principal lower apices of each girder varies between 50 metres and 6·50, so as to make up as far as possible for the difference of direction of the inclined members.

The lower members are connected by cross-shaped bracings, the bars of which are of hollow circular section. Cross bracings between struts or compression members of the two main girders give additional strength to those girders and increase their resistance to the wind.

Central Girder.—The independent span of 150 metres rests upon the ends of the cantilevers. The depth is 11 metres on the ends and 20 metres in the centre, the sides being 10 metres apart. Each girder consists of four members, the lower members being horizontal and the upper assuming the shape of a polygon inscribed in a circle, both being connected by web, forming isosceles triangles.

The two members are formed of sheet and section iron divided

These bolts have a diameter of ·250 metres, and their action extends over a height of 14 metres of masonry.

The two columns of the same pier are connected by bracings which enable them generally to resist the transverse action of the wind.

The piers terminate at the top in ledges carrying the balustrade.

A circular plate 6·200 metres in diameter, and 1·400 metres in height, covers each column, and is formed of sheet iron, serving to receive the supporting apparatus with a fixed or expanding foot.

The expansion gear comprises six rails, ·600 metres in diameter and 3 metres in length.

The load is transmitted from the floors to the piers through the bedplates, hence it is distributed all over the sheet iron plates and angle irons, braced together so as to prevent overturning under the action of the wind.

The columns of one pier are fixed, while the columns of the next pier have expansion gear. The effect of the expansion or the contraction of the flooring results in a corresponding reduction or augmentation of the play between the ends of the cantilevers and the ends of the central girders. The span rests on one side upon fixed supports, on the other on rolling gear.

§ 2. The Spans of 200 and 350 Metres.

The upper level of the rails is 72 metres above low-water level. The lower portion of the bridge is supposed to be at 62·680 metres above the low-water level throughout the whole extent of the spans of 200 metres, while in the centre of the spans of 350 metres the height above the low-water level is 66·497 metres.

The whole of the spans of 200 metres and 350 metres being similar to the spans of 300 and 500 metres, it will suffice, after what has been said in the preceding paragraph, to refer to the plans in order to comprehend the arrangement adopted with regard to this type of span.

regular industrial town on a desert part of the coast, and thus obviate any disorder that may result from so doing, either while the works are proceeding or after their abrupt completion. The fitting together of all the pieces can be mainly done in the work-yards, as regards the central spans and the cantilever arms. Once fitted up, each span will have to be freed from all the supports except those upon which it is supposed finally to rest. They must then be sufficiently shifted along the jetties to enable them to be placed on the barges provided for carrying them to their ultimate position.

The power required for hoisting the bridge is not such as to be above the capacity of hydraulic cranes. Let us, in fact, consider the case in which the difficulty appears to be most serious, namely, that of the central span of 300 metres, with 50 metres in over-hanging portions on either side, weighing 9580 tons. Supposing the co-efficient of friction to be ·10, it will be seen that the effort necessary will only amount to 958 tons. Particular attention should be paid to the arrangement of the slides.

As the pontoons must be adapted to remain upon the supports for a certain time, means must be provided for turning it round. The supporting surface is to be formed by the base of a cone carrying the turning socket. Thus, in the case of the heaviest span, a surface of 15 square metres will be obtained for 4790 tons, which amounts to 32 kilogrammes per square centimetre.

The slides will have to be strongly fixed to the masonry. To avoid their breaking under the strain they will have to undergo, they must be able to support about 500 tons at the transverse section, their width being 2·50 metres. They must evidently be about 20 millimetres thick. They will rest upon wooden cross-bars, lest, in consequence of some difficulty in the execution of the work, an excessive pressure per unit of surface should result in at any given point, the consequence of which would be a fracture of the metal.

The loading will be effected at high water. The barges will be brought up to the pontoons before the tide, and will raise it when the tide sets in. The whole will then be disengaged by transverse traction by means of winches.

There may be three barges in the case of the heaviest span.

If p be the pressure of the wind per square metre, the momentum of the wind about the line of flotation will be—

$$8{\cdot}750 \times 46{\cdot}85 \times p.$$

If θ is the incline assumed by the barges, then P (R—A) sin. $\theta = 8{\cdot}750 \times 46{\cdot}85 \times p$. P being the total displacement, and R—A being the distance of the centre of gravity from the metacentrum, this distance we have assumed to amount to 8 metres, and P is $= 16{,}500{,}000$.

Now, it is desirable that the immersed end should not go down deeper than 2^{m}, 50 :—sin. A must not exceed $\frac{2{\cdot}5}{35}$.

It follows that the pressure per unit of surface which the whole structure will be able to sustain will be equal to—

$$p = \frac{16{,}500{,}000 \times 8 \times 2{\cdot}5}{8{\cdot}750 \times 46{\cdot}85 \times 35} = 23 \text{ kilogrammes.}$$

Thus even a violent storm could not possibly cause capsizing.

But, granting that this point has been sufficiently illustrated, it may be questioned whether the portions of the bridge will not run the risk of being deformed under the strains they will be subjected to by the barges themselves during transport, especially if the operation is not carried out in perfectly fair weather.

It is obvious that if there is but little sea running, so that the waves are insufficient to influence the barges themselves, the whole operation will proceed as if they floated upon a perfectly smooth sea, so that no anomalous strains would ensue.

As to traction, or those strains that will result from gyration, it will be readily seen that they will be of no great importance, if all the operations are performed slowly—*e.g.*, the towing power necessary to tug the pontoon at a speed of eight knots will not exceed 150 tons, even if a very sharp wind happens to add to the resistance proper; such wind exercising a pressure of 10 kilogrammes per square metre, the towing power need not exceed 160 tons. Now, the pontoon has been calculated to resist more considerable transverse strains than that.

While one may reasonably depend on having fairly good weather in the Channel during the summer, it may happen, nevertheless, that the barges, upon leaving the port, may encounter a

It is equal to a moment of torsion of

$$\frac{\theta_1}{l} I_p G = P (R - A) (\alpha_1 - \theta_1).$$

But, on the other hand, if σ be the effect of the strain upon the part supporting the heaviest load, this effect is proportionate to $\frac{\theta_1}{l}$, *i.e.*, to

$$\frac{P (R - A)_1}{I_p G + lP (R - A)} = \frac{\alpha_1}{\frac{I_p G}{P (R - A)} + l}$$

From this expression we cannot yet obtain the value of σ; but we may infer from it that it is desirable, within certain limits, to multiply the number of barges.

Supposing, in effect, that they are uniformly divided, the displacement P of each will be proportionate to the distance between them, as l and $\frac{P}{l} = c$.

Let h be the distance of the centre of gravity from the part farthest off; we obtain

$$\sigma = Gh \frac{\alpha_1}{\frac{I_p G}{P (R - A)} + l} = Gh \frac{\alpha_1}{\frac{I_p G}{lc (R - A)} + l}$$

The value of l, corresponding to the maximum of σ is

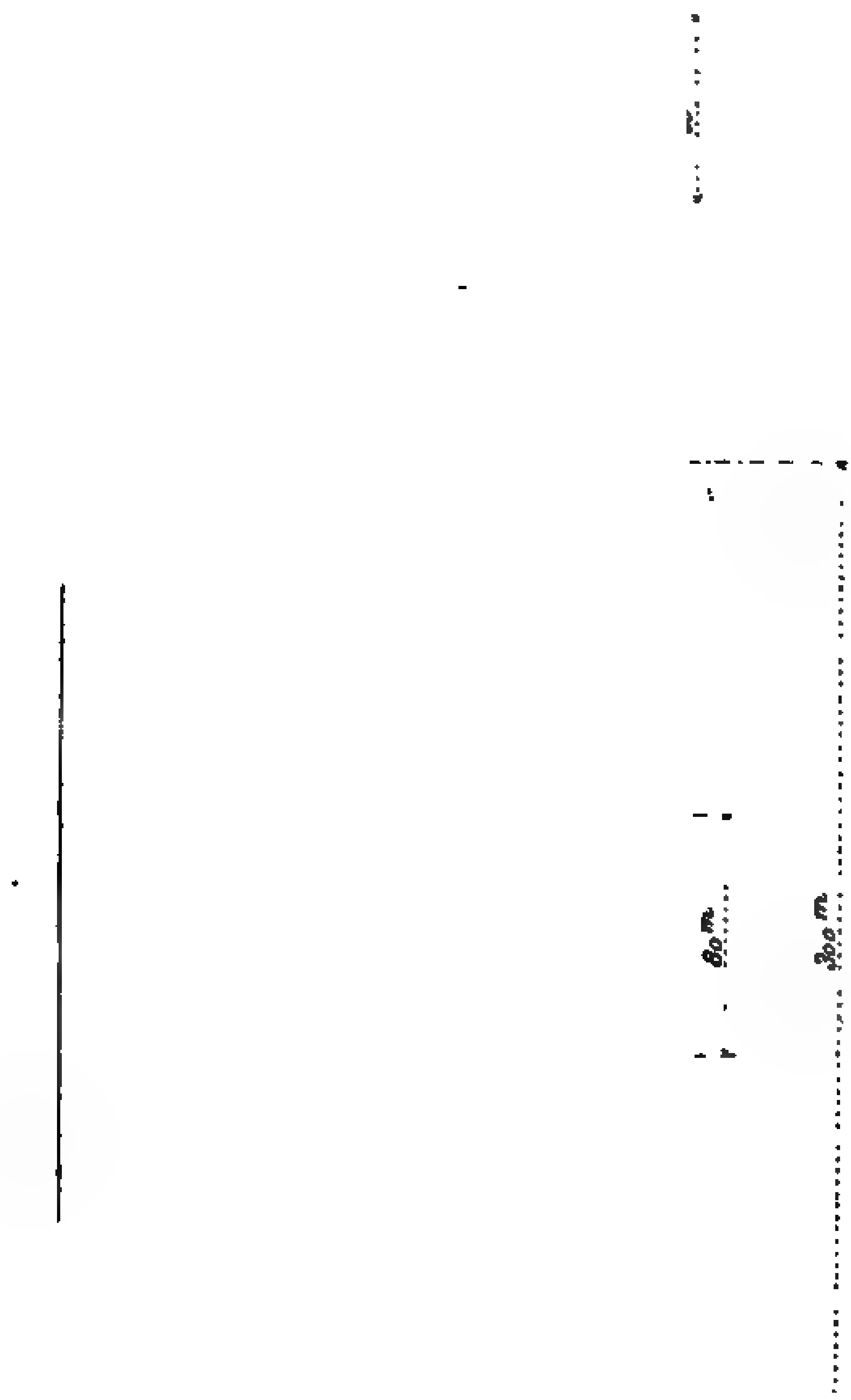
$$l = \sqrt{\frac{I_p G}{c (R - A)}}$$

By this formula a far greater length than that of the girder will be found.

As l diminishes, σ decreases too; thus it will be seen that it is desirable to increase as far as practicable the number of barges.

The necessity for the girder to rest upon parts capable of a local resistance, leads to the adoption of the number *three* for every 9·580 tons. Less than this cannot be taken in the case of the other spans.

Given a distance between the barges l, and the angle α_1, of the floating surfaces of two consecutive barges, the corresponding value may be calculated from σ. But an easier method is to


80 m.
300 m.

As to the smaller spans, where the piers of the bridge are 100 metres apart, one single auxiliary pier will be sufficient, if it be connected with the permanent pier by a platform.

VII.—ESTIMATES OF WEIGHT.

The following weights have been obtained by adding to those found by calculations 18 per cent., to provide for additional pieces that will be employed in fitting and riveting. Taking all parts together, the limit of stress is assumed to be 12 kilogrammes per sectional square millimetre, the rivet bolts not being subtracted.

This limit, however, may be considered as a very high one, for it has never been reached hitherto in any of the steel structures that have been built; but, nevertheless, after carefully examining the conditions involved in the question, it will be found that the assumption of such a limit is not unjustified.

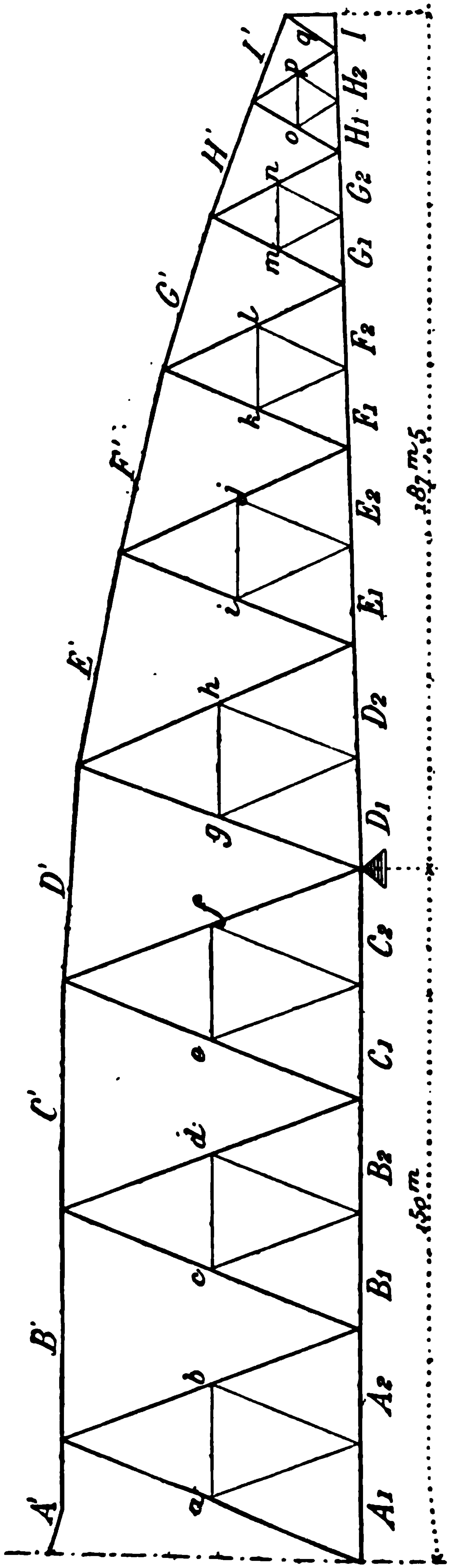
In the present case the permanent load represents $\frac{8}{11}$ of the total load. From the formulas deduced from the experiments of Wöhler, it appears that the limit of stress of 12 kilogrammes offers the same guarantees of safety as a limit of 10·5 kilogrammes in the case where the permanent load and the additional load have equal influences.

In the case of such pieces as the longitudinals under the rails, and the tension members, where the additional load greatly exceeds the permanent load, it may be said that the addition of 18 per cent. is certainly excessive—in fact, that it surpasses any figure suggested by a lengthy experience. Even as regards the other parts of the bridge, this figure may be regarded as exaggerated, owing to the use of sheet iron and section irons that can attain 12 metres in length, which would notably reduce the importance of the fittings. It must be added that in calculating these members, very liberal allowance has been made for any unforeseen excess of weight, since instead of calculating their real length, the distance between their axes has been taken into account.

To simplify calculations, the same co-efficient (12 kilogrammes) has been admitted as applying to all the members of the bridge. In a final project, however, it will be necessary to examine whether it is not more rational to assign to each part a co-efficient of resistance varying with the size and the direction of the stress to which that particular part is subjected.

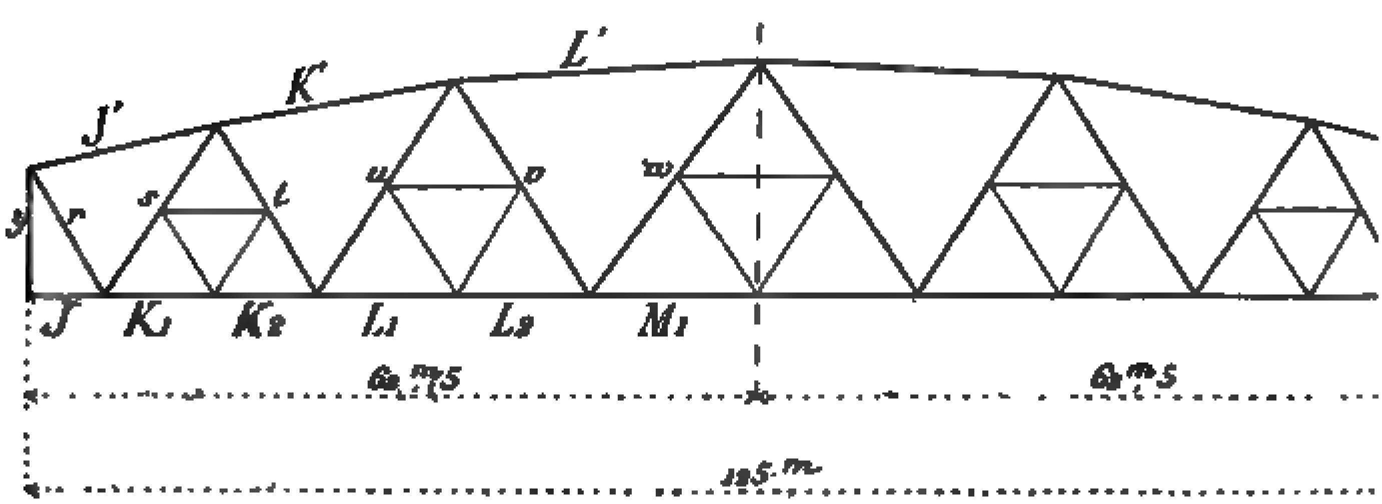
§ 1. Spans of 300 Metres and 500 Metres.

1. *Central Span and Cantilever Arms.*



Names of Parts.	One Central Span of 300 Metres.	Two Cantilever Arms of 157·5 Metres each.
	Tons.	Tons.
Main girders	5,379,684	5,594,104
Secondary bars of the main girders	67,336	55,632
Plates, rails, footways, and bracings of sleepers	411,732	[illegible]
Longitudinals under rails	335,040	380,680
Beams	106,824	97,002
Lower bracing	270,468	431,144
Inclined bracing	45,584	41,006
	6,616,668	7,101,128
Sum total	13,717,796	

2. *Central Girder of* 125 *Metres.*



Lower Members.		Upper Members.		Tension Members.	
	Tons.		Tons.		Tons.
J	2,353	J′	3,827	*y*	9,968
K_1	2,880	K′	7,409	*r*	2,715
K_2	2,327	L′	11,911	*s*	2,839
L_1	3,977			*t*	2,464
L_2	4,375			*u*	1,158
M_1	5,812			*v*	1,857
				w	0,571
	21,724		23,147		21,572

	Tons.
Main girders	265,772
Secondary bars of principal girders	11,790
Plates, rails, footways, bracings of sleepers	162,584
Longitudinals under rails	102,720
Beams	24,114
Lower bracing	16,864
Upper bracing	13,488
Inclined bracing	8,862
Total	606,194

3. *Two Metal Piers.*

	Tons.
Interior stiffening of lower members of flooring girders	60
Supporting contrivance	764
Metal columns	2,268
Bracing of columns	332
Anchor tubes	240
Anchor bolts	360
Total	4,024

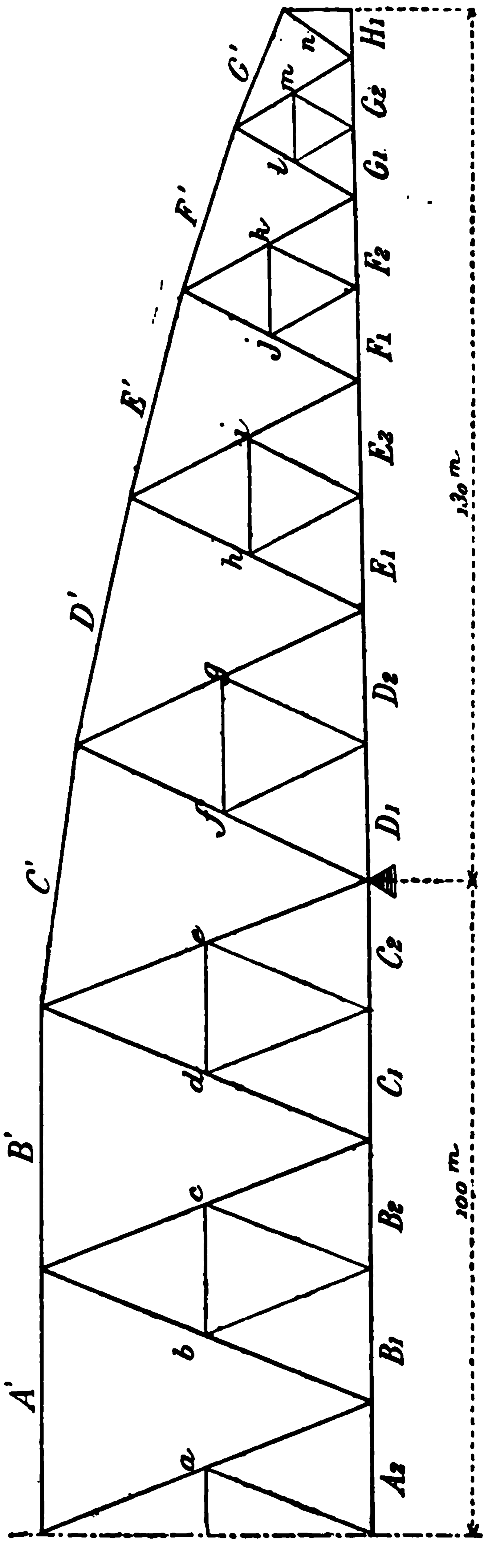
Summary.

	Tons.
Metal flooring (1° + 2°)	14,324
Piers (3°)	4,024
Total	18,348

Weight per metre of column: $\frac{18,348}{800}$ = about 23 tons.

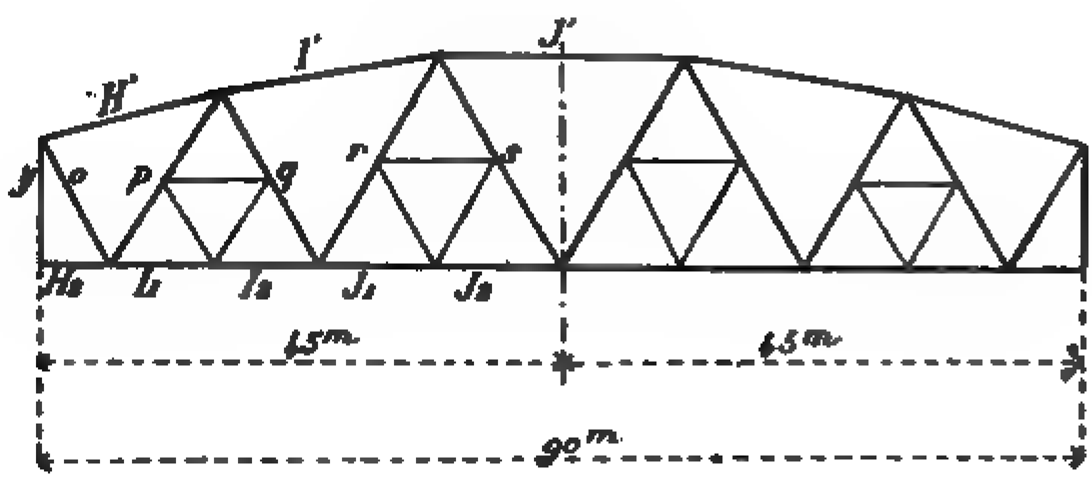
§ 2. Spans of 200 Metres and 350 Metres.

1. *Central Span and Cantilever Arms.*



Description of Parts.	One Central Span of 200 Metres.	Two Overhanging Trusses of 180 Metres each.
	Tons.	Tons.
Main girders	2,002,536	2,171,524
Secondary bars of main girders	40,000	30,300
Plates, rails, footways, bracings of longitudinals	268,752	344,384
Longitudinals under rails	207,520	263,400
Beams	67,920	[redacted]
Lower bracings	67,840	154,454
Inclined bracings	33,300	29,192
	2,687,868	3,059,650
Sum total	5,747,518	

2. *Central Girder of* 90 *Metres.*



Lower Members.		Upper Members.		Tension Members.	
	Tons.		Tons.		Tons.
H_2	1,067	H′	1,874	*y*	0,868
I_1	1,558	I′	3,899	*o*	2,715
I_2	1,265	J′	2,411	*p*	1,711
J_1	2,381			*q*	1,680
J_2	2,472			*r*	0,338
				s	0,902
	8,743		8,184		8,214

	Tons.
Main girders	100,564
Secondary bars of main girders	8,431
Footplates, rails, footways, bracings of longitudinals . .	116,776
Longitudinals under rails	84,944
Beams	19,184
Lower bracing	9,990
Upper bracing	7,984
Inclined bracing	5,442
Total	353,315

3. *Two Metal Piers.*

	Tons.
Inner framings of lower members of floor girders	28
Supporting machinery	422·8
Metal columns	1,625·2
Bracings of columns	248
Anchor tubes	180
Anchor bolts	340
Total	2,844

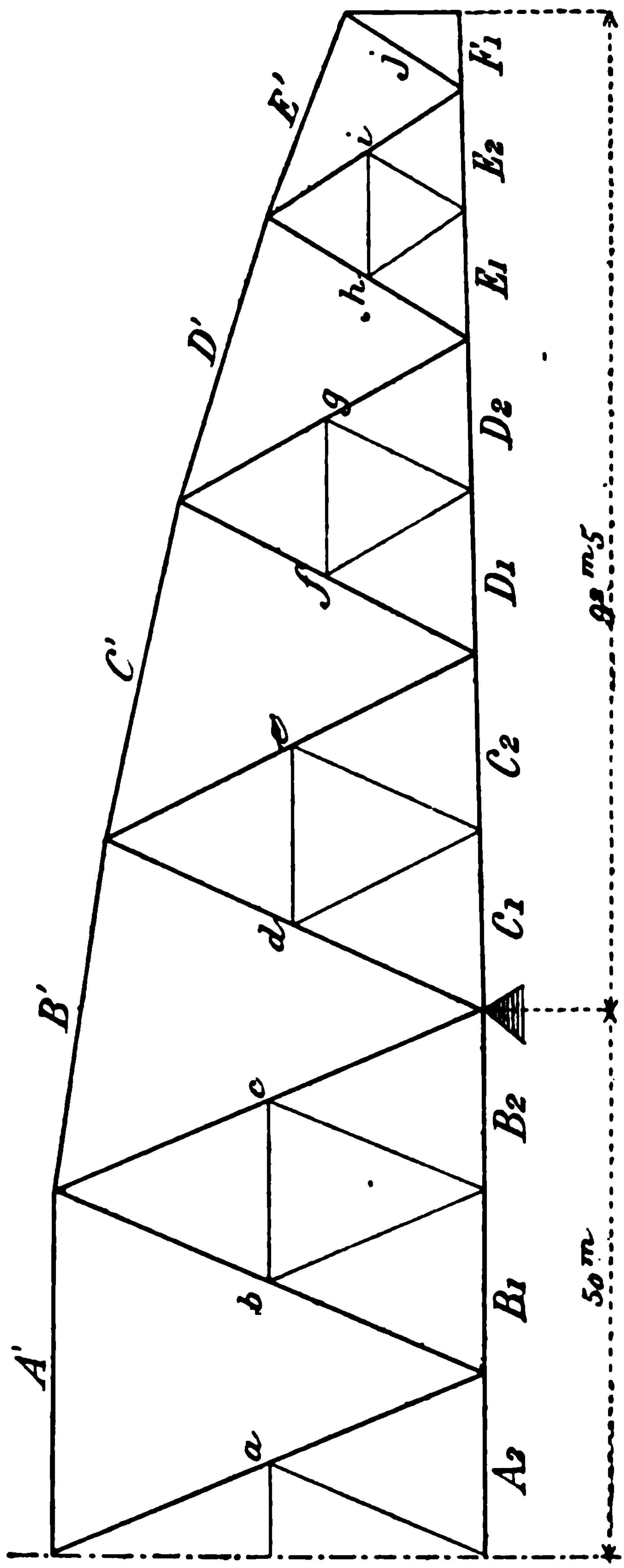
Summary.

	Tons
Metal flooring (1° + 2°)	6,101
Piers (3°)	3,844
Total	8,945

Weight per running metre: $\frac{8,945}{500}$ = about 16·3 tons.

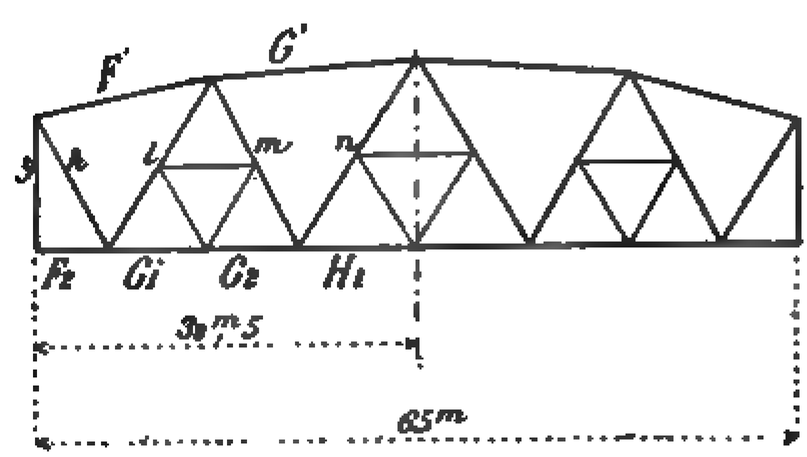
§ 3. Spans of 100 Metres and 250 Metres.

1. *Central Span and Cantilever Arms.*



Description of Parts.	One Central Span of 190 Metres.	Two Cantilever Arms of 92·5 Metres each.
	Tons.	Tons.
Main girders	623,060	946,844
Secondary bars of main girders	12,900	15,164
Plates, rails, footways, bracing of sleepers	[illegible]	243,340
Longitudinals under rails	101,184	176,280
Beams	27,600	42,952
Lower bracing	16,326	69,040
Inclined bracings	22,000	16,000
	936,570	1,508,620
Sum total	2,145,190	

2. *Central Girder of* 65 *Metres.*



Lower Members.		Upper Members.		Tension Members.	
	Tons.		Tons.		Tons.
F_2	0,628	F′	1,101	*y*	0,564
G_1	0,792	G′	2,121	*k*	1,312
G_2	0,773			*l*	0,938
H_1	2,283			*m*	1,001
				n	0,202
	4,476		3,222		4,017

	Tons.
Main girders	46,860
Secondary bars of main girders	5,770
Footplates, rails, footways, bracing of longitudinals . . .	84,336
Longitudinals under rails	57,696
Beams	15,648
Lower bracing	7,650
Upper bracing	5,714
Inclined bracing	5,442
Total . . .	229,116

3. *Two Metal Columns.*

	Tons.
Inner framings of lower members of flooring girders	12
Supporting gear	240
Metal piers	1,448
Bracings of piers	140
Anchor tubes	112
Anchor bolts	220
Total . . .	2,172

Summary.

	Tons.
Metal flooring (1° + 2°)	2,674
Piers (3°)	2,172
Total . . .	4,846

Weight of the running metre: $\frac{4846}{350} = 13{\cdot}8$ tons, approximately.

§ 4. General Summary.

Number of Spans for the whole of the Bridge.	Description of Spans.	Units.		Totals.	
		Lengths.	Weights.	Lengths.	Weights.
		Metres.	Tons.	Metres.	Tons.
32	Spans of 300 and 500 metres	800	18,348	25,600	587,136
13	„ 200 and 350 „	550	8,945	7,150	116,285
14	„ 100 and 250 „	350	4,846	4,900	67,844
	Totals for whole bridge . . .			37,658	771,265

Average weight per linear metre of bridge: $\frac{771,265}{37,650} = 20{\cdot}5$ tons.

VIII.—CALCULATIONS OF RESISTANCE.

The calculations relating to the large spans of 300 and 500 metres will alone be here reproduced, the same method having been followed for the three other types of spans.

§ 1. The Central Girder.

1. *Longitudinals under Rails.*

The two lines of rails are carried by four rows of longitudinals laid underneath the rails.

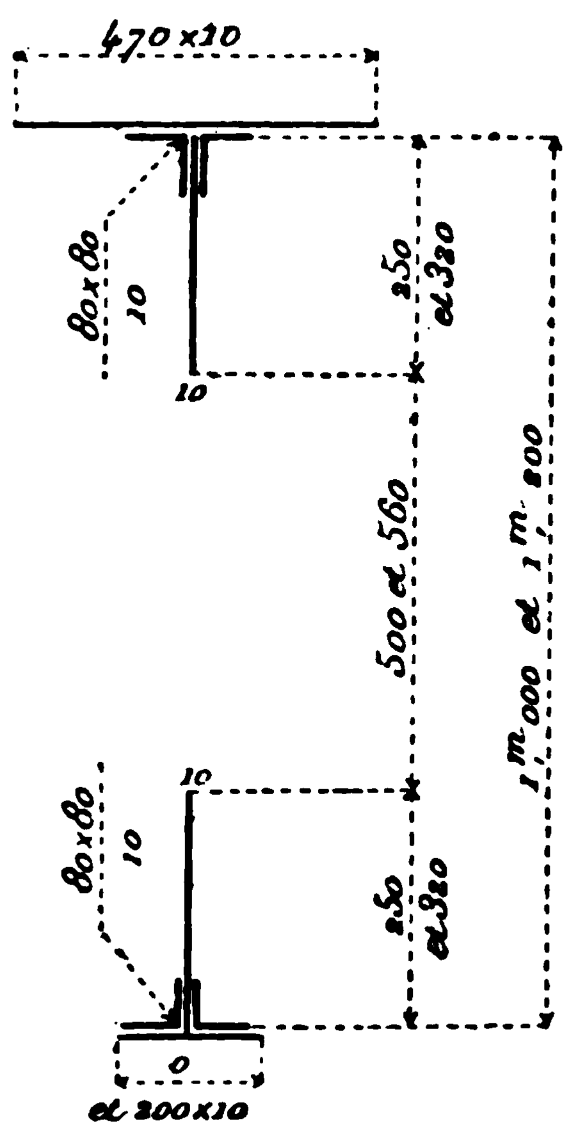
Their length varies from 6·50 metres to 14 metres.

The loads comprise:—

The weight of the rails, of the footplates, of the footways, and of the bracings of the longitudinals.

The weight of the longitudinals proper is supposed to vary with the weight under consideration.

And the additional load due to passing trains.



This additional load is assumed to be uniformly distributed according to the regulations of the 9th July 1877.

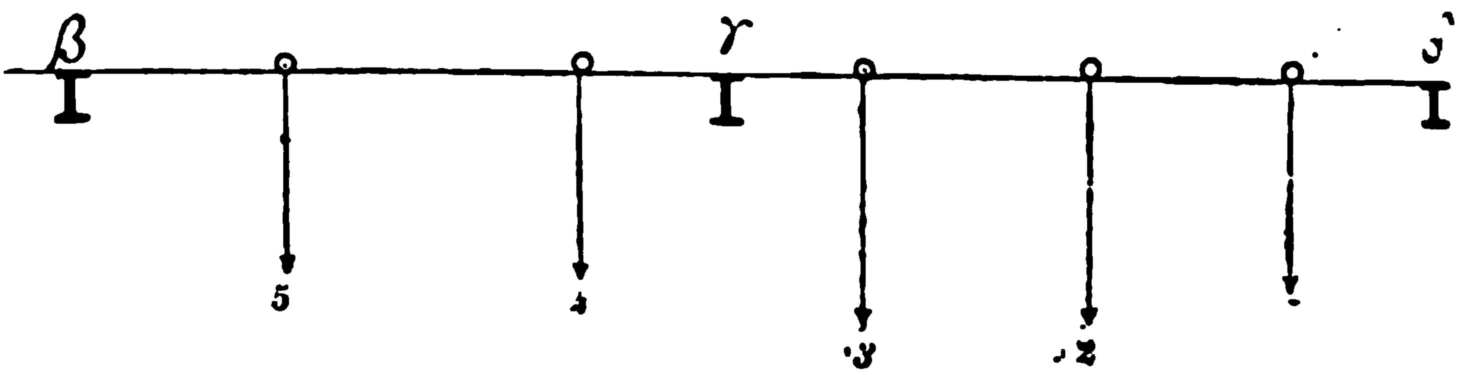
All the longitudinal beams are box-latticed.

The accompanying sketch shows their shape in cross section.

The bars of the lattice work are formed of T irons of $\frac{100 \times 60}{8 \times 8}$ and of $\frac{100 \times 61}{9 \times 8}$.

The results of the calculations of the longitudinal beams underlying the rails are contained in the following table. They have been arrived at on the assumption that the beams will be supported at the ends only:—

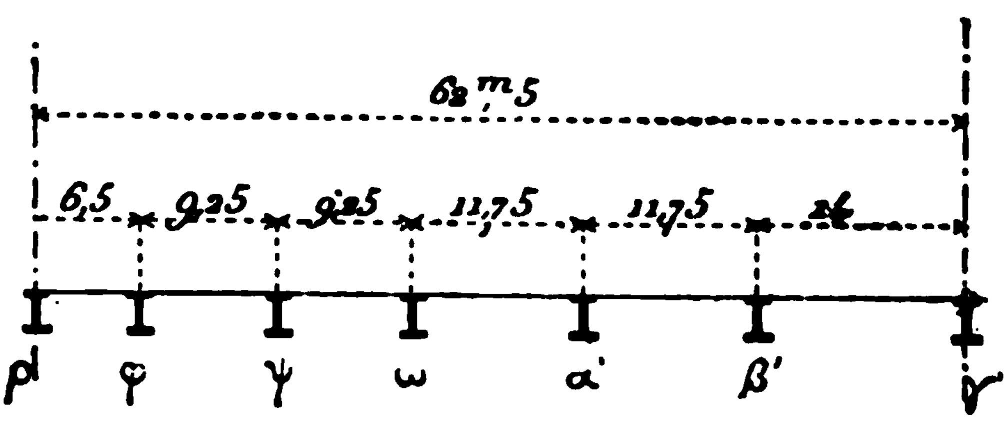
considered as two non-continuous girders, the position of the train to which the maximum of reaction of support γ corresponds, is the



same as that which produces the maximum moment of flexure under section γ of the beam sustaining the same loads, and resting upon the two supports β and δ only.

Applying, therefore, Weyrauch's construction, one is enabled immediately to find the most unfavourable position of the train, whether of simple or double traction, and to calculate the load transmitted to the beam. The results of such calculation are as follows:—

Beams.	Maximum Stress (for each Weight).	Case in which the Maximum Stress is exercised.
	Tons.	
ρ	42	Simple traction train.
ϕ	43	do.
ψ	47	do.
ω	50	do.
α'	54	do.
β'	55	do.
γ'	59	do.



Supposing all the loads supported by each member to be concentrated at its two upper apices, the science of statics enables us to determine the strains that will be developed in each of these elements, and the corresponding weights.

Lower Apices.	Span Loaded.	Span Unloaded.	Upper Apices.	Span Loaded.	Span Unloaded.
	Tons.	Tons.		Tons.	Tons.
17	4,989	5,507	17′	6,211	11,180
18	12,917	14,707	19′	14,037	24,742
19	11,706	11,102	21′	21,564	36,116
20	20,596	26,386	23′	13,217	21,966
21	15,645	15,404	...	...	...
22	27,484	35,334	...	...	...
23	9,979	10,236	...	...	...

Lower Bracing.—The whole of the lower chords of the principal girders and of the cross-shaped bracings which connect them form a girder sustaining the strains transmitted to the lower apices. This girder may be considered as imbedded in a recess at both ends. The diagrams (No. 20) show how the moments of flexure and of shearing stress have been determined.

From these the stresses developed in the chords and in the bars of the bracings, as well as the corresponding weights can be worked out.

Chords.	Stress in one Chord.	Length of one Chord.	Weight of one Chord.		Length of one Bar.	Weight of two Bars.
	Tons.	Metres.	Tons.		Metres.	Tons.
J	220,5	6,50	1,099		11,927	1,301
K_1	154,5	9,25	1,096		13,623	1,620
K_2	76,5	9,25	0,543		13,623	1,409
L_1	55,5	11,75	0,500		15,431	1,598
L_2	99,6	11,75	0,898		15,431	1,184
M_1	114,0	14,00	1,224		17,205	1,330
	Total .	.	5,360		Total . .	8,432

The following weights will thus be obtained for the whole span:—

	Tons.
Weight of the lower chords	4 × 5,360 = 21,440
Weight of the lower bracing	2 × 8,432 = 16,861

Upper Bracing.—The girder formed of the upper members and braces should also be considered as embedded in recesses at the ends. The web is of flat surface, but it is subject to the normal strains consistent with its form in horizontal sections.

Thi[illegible] to by M. Maurice Lévy, and one

selves, the weight of the metal flooring, and of additional loads. A variety of experiments show that these loads may be regarded as uniformly distributed and applied to the lower portion of the girders.

Let

p be the total per square metre of the main girder.

P the weight of a girder such as it should be to resist vertical strains.

p' the weight per running metre of girder for all parts under consideration; and

p'' the additional load per running metre of girder.

We then obtain—

$$p = \frac{P}{L} + p' + p'' \quad (1)$$

Or let

t be the tension or compression of one girder bar per unit of load and per running metre.

l the length of the bar.

π the density of the metal.

R the co-efficient of resistance per unit of surface.

The weight of a bar will then be:—

$$1 \cdot 18 \frac{\pi}{R} ptl.$$

The factor 1·18 being allowed for rivetings, joints, and fittings, the weight of one girder will then be:—

$$P = 1 \cdot 18 \frac{\pi}{R} p \Sigma tl \quad (2)$$

Eliminating p between formulæ (1) and (2), we find:

$$\frac{P}{L} = 1 \cdot 18 \pi + \frac{(p' + p'') \Sigma tl}{RL - 1 \cdot 18 \pi \Sigma tl} \quad (3)$$

Calculation of $(p' + p'')$.—If we summarise the weights of all the pieces known, we obtain:

$$p' + p'' = 4{,}555 \text{ tons.}$$
$$\Sigma\, tl = 26{\cdot}136$$
$$R = 12 \times \overline{10}^6$$
$$\Pi = 7{\cdot}800$$
$$L = 125$$

hence:

$$\frac{P}{L} = 0{\cdot}87 \text{ tons.}$$

The weight of the two girders, necessary to enable them to withstand vertical stresses, is therefore :—

$$2 \times 125 \times 0{\cdot}87 \text{ tons} = 217{,}500 \text{ tons.}$$

Adding to it the weight necessary to withstand the action of the wind, we obtain :—

$$217{,}500 \text{ tons} + 48{,}272 \text{ tons} = 265{,}772.$$

§ 2. Central Span and Cantilever Arms.

1. *Longitudinal Beams under Rails.*

The length of span of the longitudinals varies from 7·50 metres to 25 metres.

Their arrangement being the same as that of the corresponding members of the central girder, the results only of the calculations will be here indicated.

Description of Span.	Number of Longitudinals in a Row.	Length of Longitudinals.	Plates, Rails, &c., Weight per Average Metre of Sleeper.	Weight of one Longitudinal.	Weight of Plates, Rails, &c.	Weight of Longitudinals.
		Metres.	Kilos.	Kilos.	Kilos.	Kilos.
Central span . .	12	25,00	343,11	6·980	102·933	83·760
Total for one row of sleepers . .					102·933	83·760
Cantilever arms . .	4	25,00	343,11	6,980	34·311	27·920
	4	21,50	335,94	5,825	28·891	23·300
	4	18,00	333,74	4,434	24·029	17·736
	4	14,50	327,94	3,349	19·021	13·396
	4	11,00	324,37	2,431	14·272	9·724
	2	7,50	324,37	1,547	4·866	3·094
Total for one row of longitudinals .					125·390	95·170

For the four rows of longitudinals we will thus have—

Description.	Central Span of 300 Metres.	Two Cantilever Arms of 187·5 Metres each.
	Tons.	Tons.
Plates, rails, footways, and bracings of longitudinals	411,732	501,560
Longitudinals underlying rails	335,040	380,680

2. *Beams.*

The inclined members of the central span and of the cantilever arms are of the same shape as those of the central girder.

Their length varies between 23 and 9 metres, and their height from 7·60 to 3·60 metres.

The loads due to the plates, rails, &c., and the weight of the sleepers are found with the assistance of the following tables.

As regards the strain due to the passing trains, the sketch on p. 107 indicates the maximum attained in the case of each train.

Tension Members.	Maximum Strain (for one Line).	Case in which the Maximum may be attained.	Tension Members.	Maximum Strain (for one Line).	Case in which the Maximum is attained.
	Tons.			Tons.	
η'	89	Double traction train.	η	66	Simple traction train.
α	89	do.	θ	60	do.
β	85	do.	λ	58	do.
γ	81	do.	μ	52	do.
δ	76	do.	ν	48	do.
ϵ	71	do.	ρ	42	do.

In addition to this, the tension members will have to sustain two kinds of strains, the one due to the action produced by the wind upon the train and the sleepers, and the other caused by the inclination of the main girders, which will be more fully referred to farther on.

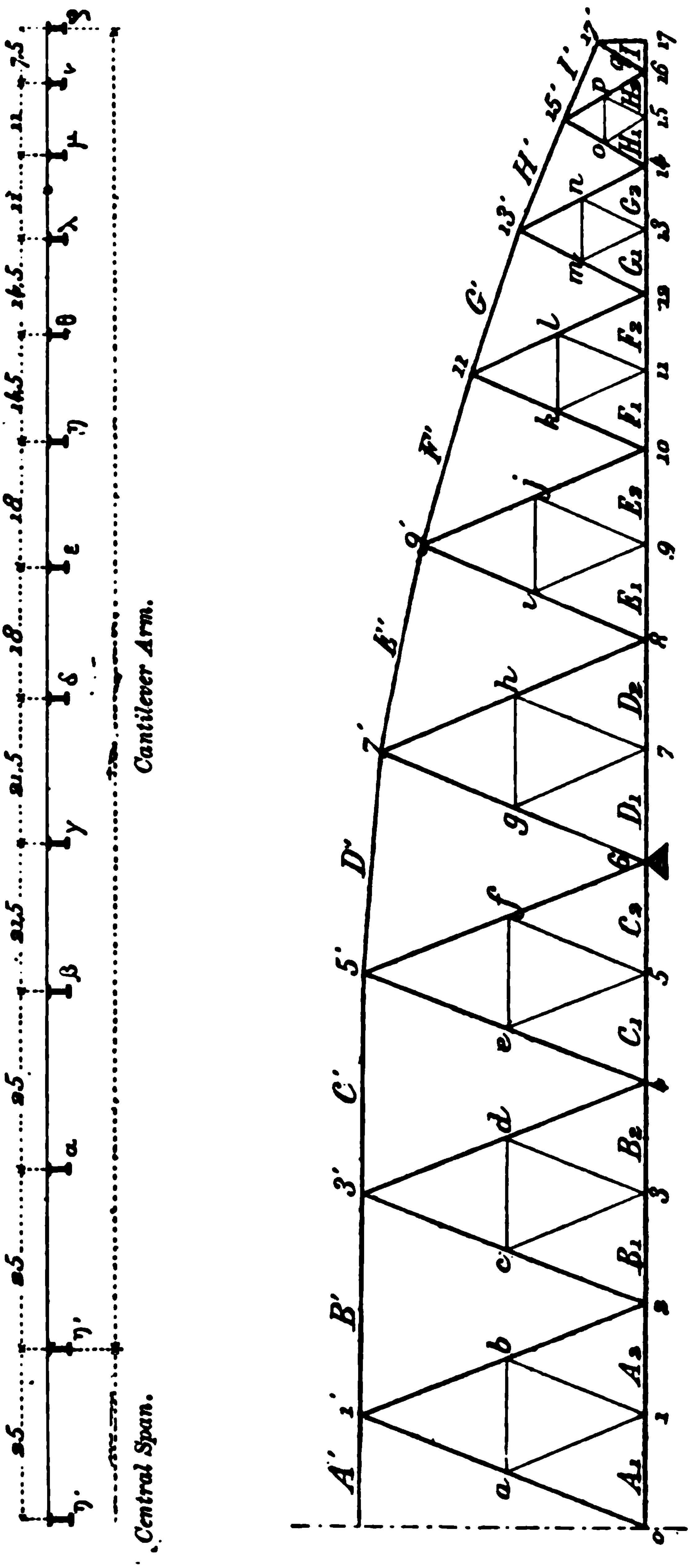
The weights attained in this connection are recorded in the following table:—

Description of Spans.	Tension Members.	Weight on each.	Number of Tension Members.	Total Weight.
		Kilos.		Tons.
Central span of 300 metres . .	η'	8,902	12	106·824
			Total . .	106·824
Two cantilever arms of 187·5 metres each	η'	8,902	1	8·902
	α	7,838	2	15·676
	β	6,776	2	13·552
	γ	6,070	2	12·140
	δ	5,114	2	10·228
	ϵ	4,182	2	8·364
	η	3,500	2	7·000
	θ	2,814	2	5·628
	λ	2,402	2	4·804
	μ	2,138	2	4·276
	ν	1,718	2	3·436
	ρ	1,498	2	2·996
			Total. . .	97·000

3. *Bracings.*

The surfaces exposed to the action of the wind have been determined in the same way as in the case of the central girder, and the force of the wind has been supposed to be the same.

It has been assumed that the loads at each apex are due to the braces that are there united to the top or bottom member. Thus the different apices would have to sustain the following pressures:—


Central Span.
Cantilever Arm.

Upper Apices.	Case of Loaded Bridge.	Case of Unloaded Bridge.
	Tons.	Tons.
1′	60,182	95,583
3′	60,182	95,583
5′	59,978	93,978
7′	59,300	93,000
9′	58,752	92,359
11′	52,569	90,432
13′	38,203	61,656
15′	24,428	40,702
17′	9,125	10,290

Lower Apices.	Case of Bridge Loaded.		Case of Bridge not Loaded.	
	Loads applied Direct.	Loads due to Sleepers and Trains.	Loads applied Direct.	Loads due to Longitudinals.
	Tons.	Tons.	Tons.	Tons.
0	40,768	11,050	66,962	7,425
1	26,908	22,100	34,506	14,850
2	81,534	22,100	133,926	14,850
3	26,908	22,100	34,506	14,850
4	81,534	22,100	133,926	14,850
5	26,908	22,100	34,506	14,850
6	70,473	22,100	125,506	14,850
7	24,557	22,100	40,666	14,850
8	62,118	20,188	99,810	13,220
9	17,816	18,275	29,713	11,610
10	41,331	16,329	72,130	9,936
11	12,723	14,382	21,250	8,262
12	27,622	12,614	49,393	6,872
13	8,887	10,846	14,426	5,481
14	18,595	9,350	32,171	4,523
15	6,091	7,854	9,628	3,564
16	11,298	6,650	16,002	2,997
17	2,798	2,878	4,712	1,215

Owing to the absence of bracings at the upper portion of the girders, it is the lower bracing that will have to resist the action of the wind.

The stresses due to the trains and to the sleepers, as well as those applied to the top apices, will therefore have to be transmitted to the lower apices.

But in order to obtain a system of forces equivalent to the first system it will be necessary to add to these forces conveyed to

principal girders, the lower bars of the tension and compression members and cross-shaped bracings, gives the form of girder which is to sustain the stresses transmitted to the lower apices (see sheet 20).

It has been shown just now what stresses would act upon each of the lower apices. To these must be added the effect of wind upon the independent span of 125 metres.

These effects are, 158,347^T when the bridge is loaded,
and 212,682 „ „ free.

They must be applied to apex 17, that is, at the end of the cantilever.

To these effects we must further add couples similar to those mentioned above. The effect of these couples is to load vertically the main girders with a weight equal to—

124,698^T when the bridge is loaded,
and 167,545 „ „ free.

These, however, will only have to be considered in calculations referring to the heavier trains.

In the case of the lower bracing, there will have to be considered at the end of the cantilever a moment of flexure equal to and acting in the opposite direction to the moment at the junctions of the lower bracing of the central girder.

On Sheet 20 the diagrams will be found which serve to deter-

Aggregate weight of all the bars of the lower bracings:—

In a central span of 300 metres	270,468
In two cantilever arms of 187·5 metres	431,144

INCLINED BRACINGS.—The bracings which connect, twos-and-twos, the struts or compression members of the main girders, must be capable of transmitting to the lower apices those stresses acting on the top apices.

The tensions and the compressions of the bars of these bracings may be determined by simple diagrams, such as are used in statics.

Stresses are also developed in the straits of the main girders.

The following tables give the results:—

Main Bars of Girders.	Weight. Bridge Loaded.	Weight. Bridge Free.
	Tons.	Tons.
a	9,170	14,600
b	9,170	14,600
d	9,170	14,600
f	9,170	14,600
g	8,294	13,000
i	6,969	10,900
k	4,686	8,100
m	2,217	3,580
o	0,746	1,250
q	0,311	0,350

Corresponding Bars.	Weight of Cross Bracings.
	Tons.
a	5,698
b	5,698
d	5,698
f	5,698
g	5,377
i	5,717
k	4,897
m	3,807
o	0,335
q	0,370
Total . . .	43,295

Total weight of the inclined bracings:—

	Tons.
In the central span of 300 metres	45,584
In the two cantilever arms of 187·5 metres, each . . .	41,006

CALCULATION OF EFFECTS DUE TO COUPLES.—The nature of these effects having been indicated above, the results of the calculations will alone be here stated.

4. *The Tension and Compression Members of the Main Girders.*

The same methods of calculation are here adopted as in the case of the independent span. The results are as follows :—

Corresponding Apices.	Weight of Tension and Compression Members.	Corresponding Apices.	Weight of Tension and Compression Members.
	Tons.		Tons.
1	4,828	9	3,784
[illegible]	5,412	11	2,134
5	6,593	13	1,116
7	6,332	15	0,541

5. *Main Girders.*

Each main girder comprises a central span of 300 metres, and the two adjacent overhanging portions of 187,500 metres each.

What has now to be determined is the weight that will enable each girder to resist vertical strains. Such strains are due to a variety of causes :—

To the weight of the plates, rails, &c.

To the weight of the sleepers under the rails.

To the weight of the beams.

To the weight of the bars of the lower bracings.

To the weight of the bars of the inclined bracing.

To the weight of the members and struts, which is necessary to enable them to withstand the effects of the wind.

To the vertical stresses due to the wind.

To the weight of the secondary bars of the girders.

To the effects due to the independent span of 125 metres.

To the additional load due to trains (assumed to be at the rate of 3 tons per metre of girder); and lastly,

To the weight of the girders themselves.

With the assistance of the preceding tables, the strains that can be applied to each main apex of the girder may be readily determined.

Owing to the method of construction of the girder, the weights of the lower members and of the struts of the girder may be regarded as transmitted to the lower apices; the top apices only being loaded with the weight of the top members.

The following table indicates the strains that are known, as applied to the apices of half of a girder:—

Apices.	Case of Bridge Loaded.	Case of Bridge Free.
	Tons.	Tons.
0	170,234	105,037
2	498,214	484,020
4	539,346	531,195
6	743,027	823,004
8	506,144	486,451
10	386,766	371,655
12	266,622	218,074
14	170,439	115,351
16	83,908	38,026
17	483,187	326,760

The inspection of this table shows that the case of the bridge being loaded is the most unfavourable one. We will, therefore, take the figures of the second column for the calculations of the girders.

Assuming that the approximate weight of the members of the girder is found by any convenient method, such weight will have to be distributed among the different apices, and by adding it to

the figures of the foregoing table we will obtain a fresh series of loads that may serve as a base for a second approximate estimate of the weight.

By repeating the same process a third approximate figure can be obtained, and the calculation may thus be continued until two consecutive approximations represent as nearly as possible the weight of a semi-girder. The stresses developed in each member of the girder have been represented statically.

The final approximations are shown in the diagrams. The results are as follows:—

Central Span.				Cantilever Arms.			
Weight of Members.		Weight of Struts.		Weight of Members.		Weight of Struts.	
	Tons.		Tons.		Tons.		Tons.
I	1,633	*q*	4,927	C	144,321	*f*	156,976
H	9,413	*p*	9,485	B	107,987	*e*	122,537
G	22,558	*o*	6,421	A	92,442	*d*	65,780
F	43,679	*n*	14,706	C′	121,117	*c*	59,267
E	79,477	*m*	12,121	B′	96,293	*b*	19,488
D	145.143	*l*	28,261	A′	45,088	*a*	13,669
I′	4,528	*k*	26,070				
H′	16,320	*j*	56,578				
G′	33,340	*i*	57,525				
F′	59,976	*h*	108,914				
E′	106,670	*g*	117,233				
D′	172,280						

These are the weights necessary to resist vertical strains.

To determine the real weights, the stresses due to the action of wind should be added.

Thus the total weights of the two main girders are as follows:—

In one central span of 300 metres . . . . . 5,379·684 tons.
For the two cantilever arms of 187·5 metres each . . 5,594·104 „

The diagrams on Sheet 19 * show that owing to the incline of the girders the compression stresses are developed in the lower bars of the struts; it has been ascertained that they are capable of sustaining these stresses.

§ 3. Metal Columns.

In determining the stability of the metal columns the following two cases have been considered:—

* These diagrams have not been reproduced in the *Journal.*—Ed.

1. When the wind acts horizontally and at right angles to the longitudinal axis of the bridge, or transversely to the bridge; and

2. When the wind acts horizontally, and in the direction of the longitudinal axis of the bridge.

In these two cases the thrust at the head of the columns due to expansion is added to the effects of the wind.

In the first case, the surfaces exposed to the wind are, with regard to the superstructure, those which have been determined by the calculations of the bracings of the main girders; and in regard to the metal columns, they represent the sum of the diametrical surfaces of the piers, which are considered as invariable throughout their height.

In the second case, the vertical projections of the members of the girders of the lower and upper bracings (supposed to be flat for a distance equal to the heights of the sums of the girder braces) and the sum of the vertical projections of all the remaining bars, beams, &c., have been taken into account in dealing with the superstructure.

Considering that all these members are comparatively close to each other, it is amply sufficient to take half of the total surfaces. In the case of the metal column the sum of the superficial diameters of the two piers and of the five rows of pier bracings has been taken.

The wind pressures are the same as those assumed in the calculations of the floor, that is to say, 270 kilogrammes per square metre in the case of the superstructure being free from any load, and 170 kilogrammes when the superstructure is loaded by trains.

	Wind.		
	Transverse.		Longitudinal.
	Floor Free.	Floor Loaded.	Floor Free.
Stress of wind pressure upon 400 metres of superstructure effecting a metal pier	2·050T	1·455T	767T
Height of the centre of pressure above the axis of the lower member . .	20m,1	19m,4	24m,3
Weight of 400 metres of superstructure effecting the metal column .	7·162T	7·162T	7·162T
Inner framings of the lower members on the right of the supports . .	30T	30T	30T
Overcharge of 6 tons per running metre of bridge	...	2·400T	...
Total . .	7·192T	9·592T	7·192T
Weight acting on one pillar . .	3·596T	4·796T	3·596T

1. *Stability under the Action of Transverse Wind.*

Bed Plates.—The greatest load supported by a bed plate is that which results at the time when the bridge is subjected to additional load.

The distance between the base of a bed plate and the axis of the lower member is 1·4 metres.

The load is expressed by the following formula :—

$$C = P + \frac{M}{\delta}$$

Load due to the superstructure . . . 4·796 tons.
Load due to the bed plate and accessories . 6 tons.

$$P = 4802 \text{ tons.}$$

M, being the moment of overturn under the action of the wind, is equal to 1·455 tons × (19·4m. × 1·4m.) = 30·26 tons.

δ, being the distance of the columns, equals 25 metres.

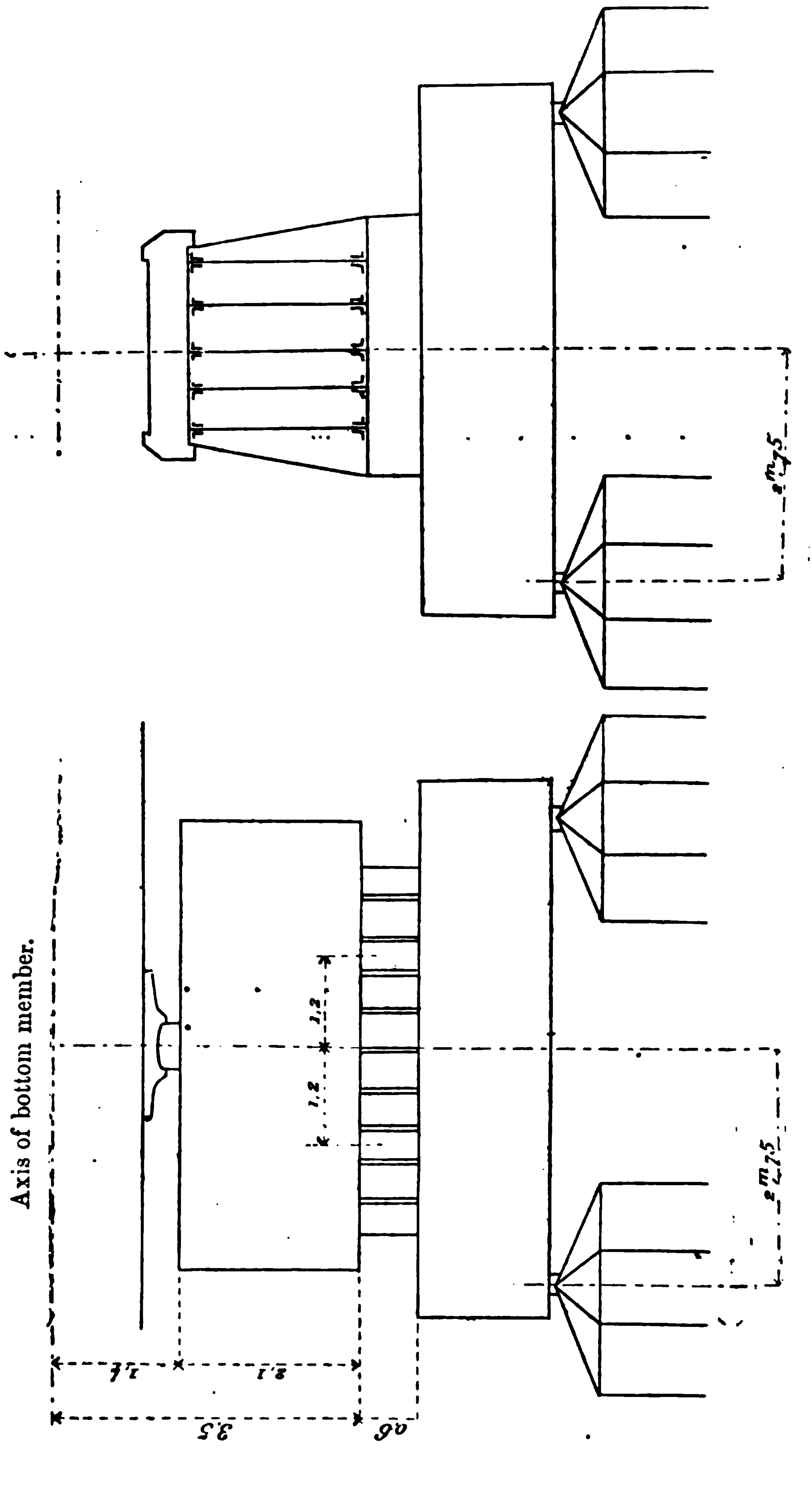
$$C = 6{,}012{\cdot}6 \text{ tons.}$$

The surface of support for the bed plate is 2m. = ·5m. = 1m².

The crushing stress is equal to—

$$R = 6\text{K per square millimetre.}$$

STABILITY ABOVE THE ROLLERS.



expansion slides is required to resist equals 6196 tons. The weight of ten rollers together is 45 tons. Each roller supports at its base a load of

$$\frac{6196 + 45}{10} = 624 \cdot 1 \text{ tons.}$$

The strain per unit of surface, according to M. Contamin, is—

$$R^3 = \frac{9}{64} \frac{EQ^2}{l^2 r^2}$$

R being the stress to be determined.

E the modulus of elasticity $= 22 \cdot 5 \times \overline{10^9}$.

Q weight of a roller $=$ 624,100.

l length of a roller $=$ 3m.

r radius of a roller.

$$R = 11 \cdot 51\text{K per } {}^{m}/_{m}{}^{2}$$

The thrust whereby the rollers are set in motion, which will be considered farther on, is equal to—

$$F = \frac{a}{2r} Q \text{ for each roller.}$$

a being the width of the deformed portion that has undergone expansion.

$$\frac{a}{2r} = \frac{1}{2} \sqrt[3]{\frac{24Q}{Elr}} = 0{,}000{,}529 \sqrt[2]{Q}$$

CIRCULAR ROLLER SUPPORTS.—The supports rest upon columns by means of a circular support 2·75 metres in radius. They are formed of two circular plates of 60 millimetres thickness, the inner distance between them being 1·28 metres. They are strengthened by ribs and crowns of sheet-iron, and by angle irons. The total pressure sustained by the rollers is 6241 tons. The rectangle formed by the end rollers has a surface of—

$$4 \cdot 2\text{m} \times 3\text{m} = 12 \cdot 2\text{m} \cdot 6.$$

The pressure per square metre is equal to—

$$\frac{6241}{12 \cdot 6} = 496 \text{ tons.}$$

Supposing that the load is the same throughout the surface of the plate, the maximum stress, according to the formula of MM. Lévy, would be—

$$R = p \frac{a}{h^2 - h_1^2}$$

The co-efficient 1·18 is the allowance made for the fittings and rivetings.

π being the specific gravity of the steel = 7·8.

l being the length of the segment of pier under consideration.

These two expressions will give—

$$p = \frac{P + P + \frac{Mn}{r^2}}{\frac{R}{1{,}18\,\pi\,l} - 1}$$

Thus it is this formula which serves to determine the weight of the segments of the pier. The load is less than that indicated in the case of a longitudinal action of the wind, and it is only mentioned here in passing.

STABILITY AT THE BASE OF THE PIERS.—The conditions of stability under the action of transverse wind are indicated in the following table:—

Particulars.		Bridge Free.	Bridge Loaded.
Wind on superstructure	v	2·050T	1·455T
Height of centre of pressure	g	61m,1	68m,4
Moment of overturn	$vg=m$	125·255Tm	87·882Tm
Wind upon expansion slides	v'	6T	3T,8
Height of centre of pressure	g'	38m,55	38m,55
Moment of overturn	$v'\,g'=m'$	231Tm,3	146Tm,5
Wind on piers	v''	162T	102T
Height of centre of pressure	g''	18m,75	18m,75
Moment of overturn	$v''\,g''=m''$	3·037Tm,5	1·912Tm,5
Total moment of overturn	$m+m'+m''=M$	128·523Tm,8	89·941Tm
Total stress of wind at base	$v+v'+v''=V$	2·218T	1·560T,8
Weight of metal flooring	p	7·192T	9,592T
Weight of supporting apparatus and metal columns	p'	1·982T	1·982T
Total weight	$p+p'=P$	9·174T	11·574T
Half distance between the piers	$\frac{1}{2}\delta$	12m,5	12m,5
Moment of stability	M_s	114·675Tm	144·675Tm
Ratio of moments	$\frac{M_s}{M_r}$	0,89	1,6
Relation of the stress of the wind to the load	$\frac{V}{P}$	0,24	0,13

SUBSTRUCTURE OF PIERS.—The substructure of the piers produces maximum pressures on the masonry in the case of wind

acting longitudinally. The calculations in this connection are reproduced farther on.

Anchor Tubes.—When the bridge is not loaded, the stability at the base of the piers can only be ensured by means of anchorings or holding-down bolts.

The pull on these pieces is represented by this formula.

$$T = \frac{M}{\delta} - P.$$

M being the moment of overturn at the base of the piers = 25m.

δ the distance between the piers $= \frac{9{\cdot}74}{2} = 4{\cdot}587$T.

P the weight acting on the base of the piers = T = 554.

The section of the centre tube alone is ·3237 square metres.

The strain at the anchorings, therefore, is insignificant.

Anchor Bolts.—By the effect of expansion the tubes are caused to oppose little resistance to the overturning strain, being situated in the centre of the piers, but here the anchoring bolts have to be considered. They have a maximum stress to sustain in the case of longitudinal wind. We will refer to them farther on.

Stability of the Masonry at the Level of the Tie-Bands.—The height of the masonry that is subject to the effects of anchoring must be such as to prevent lifting.

The maximum and minimum pressures may be represented by this formula—

$$C = \frac{P+p}{S} \pm \frac{Mn}{I}.$$

The quantities expressed in this formula are indicated in the following table:—

Weight of metal parts	P	9·174T
Height of anchoring	h	14m
Surface at the top of the masonry	S	625m²,8
Weight of masonry without the sloping portion	p	21·028T
Total weight at level of tie-bands	$P+p$	30·202T
Moment of overturn at level of substructures	m	128·523Tm,8
Stress of wind at level of substructures	v	2·218T
Moment of overturn	$vh=m'$	31·052Tm
Stress of wind upon masonry	v'	64T,4
Moment of overturn	$v' \times \frac{1}{2}h = m''$	450Tm,8
Total moment of overturn	$m+m'+m''=M$	160·026Tm,6
Value of n	n	21m
Value of I	I	77·991,6
Pressure upon masonry on the windward side	C	0k,5 par c.m.²
Pressure upon masonry on the leeward side	C	9k, 1 par c.m.²
Total pressure of wind	$v+v'=V$	2·282T,4
Relation of wind to the load	$\frac{V}{P+p}$	0,075

The expansion which tends to overturn the column in the direction of the length of the bridge does not to an appreciable extent alter the results indicated above.

2. *Stability under the Action of Longitudinal Wind.*

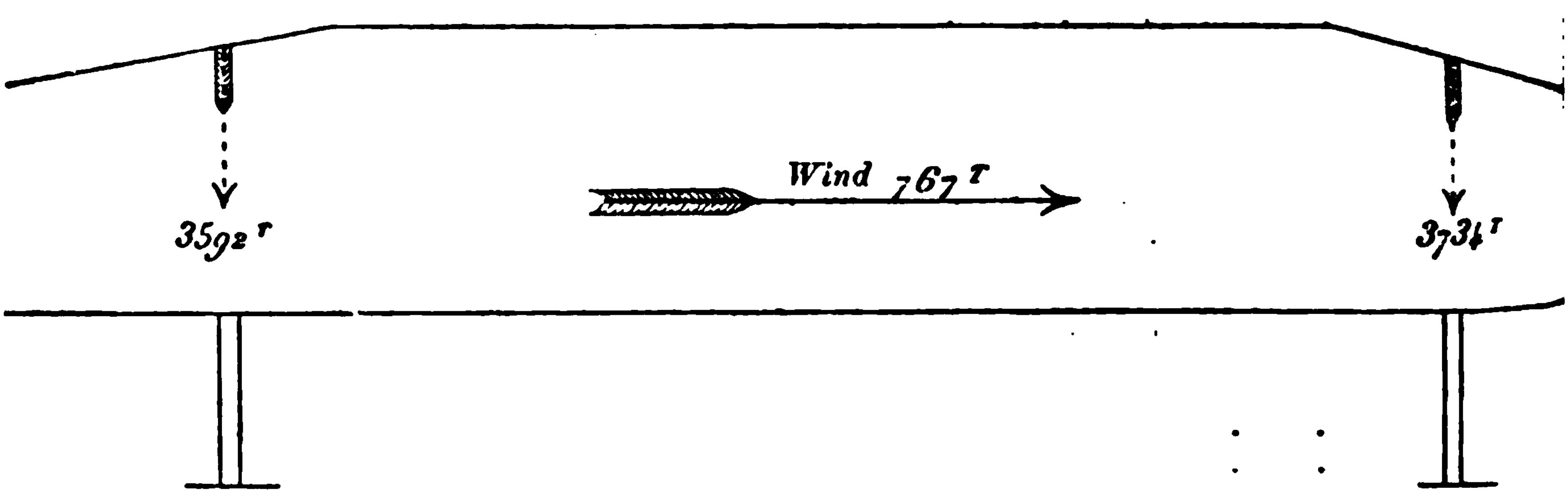
When the action of wind is longitudinal, the thrust felt at the head of the piers joins the strain due to expansion. The piers which support the rollers cannot exercise a resistance more powerful than is the strain which is capable of setting such rollers in motion. The consequence is that the difference is transmitted to the piers with fixed supports, those without expansion rollers. The greatest overturning strain further acts upon the piers on the leeward, without expansion rollers, when the bridge is not loaded.

The vertical strain that acts above the rollers is equal to $P \pm \frac{M}{a}$.

The values of this formula are indicated in the following table:—

Weight of metal parts on pier	P	3·663T
Pressure of wind upon 800 metres of girder . . .	V	767T
Height of centre of pressure above the rollers . .	H	27m,8
Moment of overturn	VH = M	21·322Tm,6
Distance of piers	d	300m
Vertical stress upon rollers (windward piers). . .	...	3·592T
Vertical stress upon leeward piers	...	3·734T
Load upon one roller $\frac{3·592T + 45T}{10}$	Q	363·700k
Co-efficient of rolling friction according to the formula found before, namely, $0,000·529 \sqrt[3]{Q} =$	K	0,038
Strain required to set the rollers in motion . . .	3·637T × 0,038	138T,2

Method of Determining the Strains at the Head of the Pillars above the Level of the Rollers.



With rollers. Without rollers

→	138T,2	. . . Contraction . . .	138T,2	←
→	0	. . . Wind	67T	→
→	138T,2	. . . Resultant . . .	628T,8	→

Thus the pillars at their heads have to sustain a maximum strain of 628T.8.

METAL PIERS.—The piers support the weight of all the metal parts, and at the same time resist the action of longitudinal wind and the flexure produced by the horizontal stress at the heads, which is 628T.8, being due to the combined effects of the wind and the expansion of the superstructure.

Taking any desired section of the pier, we must have

$$R = \frac{P}{S} + \frac{p}{S} + \frac{n}{Sr^2}(M + m + m')$$

R being the strain sustained by the metal per unit of section = 12 kilogrammes per square millimetre.

P weight of the known metallic parts.

p weight of part of the pier under consideration (the value of this has to be determined).

M moment due to the horizontal stress at the head of the pier.

m moment due to the stress of wind acting upon the bracings, such stress being centred upon each apex.

m' moment of force of the wind upon the pier.

n distance of web farthest from the centre of gravity of the section.

r^2 the section of the radius of gyration of the section under consideration.

S′ section of part of pier of a value of

$$S = \frac{p}{1.18\pi l}.$$

1·18 being the co-efficient which makes allowance for the fittings and rivetings.

π specific gravity of steel = 7·8.

l length of the pier segment under consideration.

From these two expressions the following formula results:—

$$p = \frac{P + \frac{n}{r^2}(M + m + m')}{\frac{R}{1 \cdot 18\pi l} - 1}$$

The weight of each of the parts of the pier has been determined with the assistance of this formula. The minimum thickness of 10 millimetres has been maintained with regard to all the samples of steel of which the sections are composed.

STABILITY AT BASE OF PIERS.—The stability at the base of a pier cannot be given unless by taking into account the anchor bolts. The foundation-plate in contact with the masonry presents a circular surface with portions cut out.

The maximum pressures transmitted by this plate to the masonry are expressed by the following formula:—

$$C = \frac{P}{S} \pm \frac{Mn}{Sr^2},$$

the values of which appear in the following table:—

Vertical load above rollers	p	3·734T
Weight of the parts of the pier situated above the upper level of the rollers	p'	924T
Total vertical load upon superstructure of pier	$p+p'=P$	4·658T
Surface of foundation-plate	S	69m²,68
Crushing strain on masonry per square centimetre	$\frac{P}{S}$	6k,7
Horizontal stress on head of pier	F	628T,8
Height of centre of action above the substructure	H	37m,5
Moment of overturn	$FH=m$	23·580Tm
Wind upon bracings	v	74T,6
Height of centre of pressure	h	17m,8
Moment of overturn	$vh=m'$	1·327Tm,9
Wind on pier	v'	82T,5
Height of centre of pressure	h'	18m,75
Moment of overturn	$v'h'=m''$	1·546Tm,9
Total moment of overturn	$m+m'+m''=M$	26·454Tm,8
External radius of the foundation-plate	n	6m,2
Square of the radius of gyration	r^2	10,97
Effect on masonry from flexure per square centimetre	$\frac{Mn}{Sr^2}$	±21k,5
Maximum compression on the leeward side per square centimetre	C	28k,2
Maximum compression on the windward side per square centimetre	C	−14k,8
Horizontal stress at level of substructure	$F+v+v'$	785T,9
Relation of horizontal stress to vertical load	$\frac{F+v+v'}{P}$	0,17

The anchor bolts or holding-down bolts oppose the overturning tendency. Their maximum tension is assumed to be—

$$t=\frac{1}{S}\left(\frac{Mn}{r^2}-P\right).$$

The values of this formula are as follow:—

Diameter of bolt		0m ,25
Sum of sections of 12 bolts		0m²,589
Moment of overturn		26.454Tm,8
Radius of circle of bolts, virtual value	n	5m ,55
Square of radius of gyration	r^2	15 ,4
Vertical loads	P	4.658T
Maximum tension per square millimetre	t	8k ,26

STABILITY AT BASE OF ANCHOR BOLTS.—The maximum and minimum loads on the masonry at the level of the tie-bands is expressed in the following formula:—

$$C=\frac{P+p}{S}\pm\frac{Mn}{I},$$

the different values of which are indicated in the following table:—

Weight of metal parts for two piers	P	9·316T
Height of anchorings	h	14m
Surface of masonry at top	S	625m²,8
Weight of masonry without the sloping portion	p	21·028T
Total weight at level of tie-bands	$P+p$	30·344T
Moment of overturn at level of substructures of the two piers	m	52·909Tm,6
Horizontal stress at level of substructures	F	1·571T ,8
Moment of overturn	$Fh=m'$	22·005Tm,2
Stress of wind upon masonry	$=v$	158T ,8
Moment of overturn	$v\times\frac{1}{2}h=m''$	1·111Tm,6
Total moment of overturn	$m+m'+m''=M$	76·026Tm,4
Value $\frac{I}{n}$ of the surface of the masonry	$\frac{I}{n}$	1·683 ,6
Crushing stress per square centimetre	$\frac{P+p}{S}$	4k ,8
Maximum flexure per square centimetre	$\frac{Mn}{I}$	4k ,5
Minimum pressure on windward masonry per square centimetre	C	0k ,3
Maximum pressure on leeward masonry per square centimetre	C	9k ,3
Horizontal stress at level of tie-bands	$F+v$	1·730T ,6
Relation of horizontal strains to load	$\frac{F+v}{P+p}$	0 ,057

DISCUSSION.

The PRESIDENT said that, before asking any one to open the discussion, he thought he ought to say that it was desirable that members should confine themselves, in the consideration of the paper, to the question as it affected the use of iron and steel, and also as to its mechanical construction. The political questions and the questions of navigation which arose were not subjects that the Institute would consider itself competent to treat. He would, therefore, ask members, in discussing the paper, to confine themselves to the points affecting them as members of the Iron and Steel Institute, and as mechanical engineers. It would be very appropriate if the discussion was opened by their past-President, Mr. Daniel Adamson, who was competent to deal with many of the questions raised in the paper.

Mr. DANIEL ADAMSON said he should be very glad to follow the lines that the President had shadowed forth, but he had an impression that it would be impossible to look at this great international subject without considering its ultimate value, and whether they or the French nation might not be giving twenty-five shillings for a sovereign. The probabilities of carrying out this proposed project depended, of course, on commercial considerations; and in competition with it, they had also before them, that which had repeatedly been made known, both in France and in other countries of Europe, the prospective construction of a tunnel, and a tunnel through ground that was exceedingly favourable for such an undertaking. They could not hide from themselves the fact that any superstructure carried across such a channel must largely interfere with the free pathway of nations, which had a right to run steamers in every direction at will without interruption. They were also bound to look at what would be the real and prospective position of international competition ten years hence, when this great structure would be likely to be completed, if the money was ever found to commence it with. It was more

structure were concerned, he thought they might rest assured that there would be no risk of failure. If there was failure at all, it must be in the piers or the foundations, subject as they would be to the action of the waves, and resting in a position where, perhaps, it would be somewhat difficult for human energy to make them secure in every case. Presuming, however, that the structure was finished, and all made secure, he thought it would be more liable to accident than any other means of getting across the Channel. A single collision, knocking a piece of the structure into disorder, would be very likely to stop operations, and the traffic on the bridge, for six or twelve months afterwards, a circumstance very undesirable for those who might have the courage to put their money into such a work. The importance of this subject demanded serious consideration from an international point of view, and he was not one to blame the authors for bringing it forward. In the olden times, there had been as much said against new developments as could be said to-day, and railways in their infancy met with even greater opposition than this bridge had encountered at present. Seeing, therefore, the ultimate advantages that the authors might suggest, he (Mr. Adamson) was bound to confess that he, for one, would never say a harsh word against an enterprise which had for its foundation the commercial development of nations, and the increase of the peace and comfort of all peoples. Under all the circumstances, they were bound to give a hopeful and encouraging expression to those who were deeply and directly interested in such a great national and international work as had been submitted to them that morning, and he agreed with the President that it was a great honour that this paper should have been offered for the consideration of the members of the Iron and Steel Institute.

Mr. TYLDEN-WRIGHT said he should not like the discussion to close without a warm expression of thanks to the authors on the part of one who had taken a considerable interest in the question of the Channel Tunnel. Those who had believed in that enterprise, and done what they could to support it during the last six or seven years, were very much pleased that there was another scheme now prepared to help them in pushing and

Chemically the change in producing this water-gas is expressed by $H_2O + C = H_2 + CO$. Now, the heat required to tear away hydrogen from its associated oxygen in water is not less than that which is evolved when these two gases unite; hence $2 \times 34{,}200 = 68{,}400$ calories. The weight of the combining equivalent of the carbon required to effect the change is twelve times that of the two units of hydrogen, and the heat generated by this quantity of carbon being burnt to carbonic oxide is $12 \times 2400 = 28{,}800$. Thus something more than $14\frac{1}{4}$ units of weight of carbon will be required to generate one unit by weight of hydrogen.

Now as only six units of carbon are being burnt, in the cylinder, for this quantity (one unit) of hydrogen, it will easily be understood that the incandescent carbon, which has served to generate the water-gas, is very speedily cooled below the temperature required for the decomposition just described. When this point is arrived at, the steam is shut off, and air is turned on again, in order to obtain a store of heat ready for a further production of water-gas. Thus, it will be seen, the operation consists in alternately making producer-gas, which, when using coke, is a mixture of carbonic oxide and nitrogen, and water-gas, with which we are now more immediately concerned. In calculating the amount of heat required to supplement that generated before commencing to make the water-gas, all we need to know is the quantity of carbon burnt to the condition of producer-gas, and that which enters into the composition of water-gas. According to the work I have already quoted, 25 per cent. only of the actual carbon used enters into the latter, the other 75 per cent. being converted into producer-gas, containing 68 per cent. of inert nitrogen. From 25 parts by weight of carbon there will be generated of water-gas 62·50 parts, containing 4·16 of hydrogen and 58·34 of carbonic oxide. The producer-gas from the remainder (75 parts) of the carbon will weigh 551·19 parts, of which 376·19 will be incombustible nitrogen and 175 carbonic oxide. The following estimate contains the full quantity of heat these two gases are capable of generating by their combustion:—

and 61 per cent. of the weight. The carbon in the coal gas amounts to 109·52 grammes, which is considered to remain unchanged in the producer-gas. The carbon thus burnt for the producer-gas is 2·88 to 1 for that in the water-gas, instead of 3 to 1, as allowed in the description, when coke was employed.

From these figures it follows that we are concerned with 1041·4 grammes of carbon, as carbonic oxide in the two gases, and 109·52 grammes, contained in the 370 litres, equal to 206·83 grammes, of coal-gas.

The heat capable of being produced by these two substances is—

Carbon, 1041·4 × 8000 = 8,331,200 + 206·88 coal gas × 10,000 = 2,068,800 = 10,400,000.

When converted into water and producer gases, we have to deal with the following quantities of heat by their combustion:—

Water-gas containing hydrogen from steam,	44·8	grammes	× 29,400 = 1,317,120*	
,, ,, carbonic oxide,	625·0	,,	× 2,400 = 1,500,000	
				2,817,120
Producer-gas containing coal gas,	206·83	grammes	× 10,000 = 2,068,800	
,, ,, carbonic oxide,	1805·19	,,	× 2,400 = 4,332,456	
,, ,, nitrogen,	3921·23	,,	... ...	
				6,401,256
				9,218,376

These two sets of numbers show, therefore, a loss of 11·36 per cent. in gasifying the coal.

It is perhaps worth comparing the assertion made in the pamphlet, in general terms, as to the relative proportion of carbon received in the form of water-gas and as producer-gas.

In the equation H_2O+C, we have H_2+CO for water-gas.
,, ,, O_3+C_3, ,, $3\,CO$ for producer-gas.

The weight in the two equations of H is 2, and that of carbon 48, or 1 of H to 24 of carbon. Of oxidised carbon, in the example just examined when using raw coal, there was in the gases 44·8 of hydrogen, and 1041·51 or 23·24 of carbon, for 1 of hydrogen. Now, the heat of 24 parts, by weight, of carbon burnt to carbonic oxide means 57,600 calories, which have been expended to obtain 1 part of hydrogen, which, when burnt to steam, is worth 29,400 calories—the loss being, therefore, nearly 50 per cent. of the heat generated, in order to obtain the single unit of hydrogen.

* Hydrogen burnt to water gives 34,200 calories, and to steam only 29,400 calories.

bered that this less important combustible gas represents something like 68 per cent. of the heating power of the two gases, against 32 contained in the water-gas.

I am, however, at a loss to understand whence this inference is drawn as to the inefficiency of solid fuel. The raising of steam, and smelting the ores of iron, may certainly be included within the category of "ordinary circumstances," and yet it is no uncommon thing for fuel to evaporate 60 per cent. of its theoretical quantity of water, and, as regards our blast furnaces, having regard to the chemical conditions to be observed, 90 per cent. of the full power of the fuel is accounted for by the duty performed.

To account for a supposed inferiority of solid fuel, it is assumed by the author, from whom I am quoting, that it is imperfectly oxidised. I have to do with a large number of boilers fired with coal, and at the Clarence Works we frequently consume 120 million cubic feet of blast furnace gas per day. I am prepared to assert that oxidation, in my experience, is as complete with the one kind of fuel as with the other. The quantity of heat evolved by each is, of course, easily ascertained—the only disturbing cause in any comparison between the two is the volume and temperature of the gases resulting from combustion. In this particular, no doubt, the net loss is in favour of water-gas, because the exchange of carbonic oxide for hydrogen necessarily reduces the weight of the chimney-gases passing away.

I propose now briefly to summarise the results in the following manner:—

1st. A specimen of coal, containing 70 per cent. of fixed carbon, 16 per cent. of coal-gas, and 14 per cent. of ash, nitrogen, &c., will be examined in a calorific point of view, and its power stated when simply burnt in an ordinary furnace.

2nd. Producer-gas, as supplied to the open-hearth steel furnace, obtained from the same coal, and its heating power also ascertained.

3rd. The same coal converted into water-gas and producer-gas by the processes described, and the united power of these two products calculated as before, on the supposition that for 1 of carbon in the water-gas 3 of carbon is found in producer-gas.

1. Coal as burnt in an ordinary furnace:—

	Calories.
100 parts, yielding 7200 calories per unit = ...	720,000
Chimney-gases, estimated after making the necessary allowance for oxygen in the coals, 1129 units × 427° c. × ·24 Sp. heat =	115,700

Loss in this case by chimney-gases is equal to 16·07 per cent.

2. Producer-gas from the same coal as that used in Siemens furnaces, without the addition of steam.

	Calories.
70 of carbon will give 133·33 of carbonic oxide × 2400 =	391,992
16·00 of coal-gas × 10,000 =	160,000
Sensible heat transmitted to furnace	62,411
	614,403
Heat in chimney-gases, 1129 × 377° c. × ·24 S. heat =	102,151

Loss at the chimney equal to 16·61 per cent.

In the former statement respecting producer-gas, no note was taken of the sensible heat, because it was wished to compare the heat evolution with the water-gas process, where the gases are cooled.

3. Water-gas and its accompanying producer-gas:—

		Calories.
Water-gas, 17·5 of carbon = carbonic oxide,	40·83 × 2400 =	97,992
Hydrogen from steam . .	2·926 × 29·400	86,024
		184,016
Producer-gas, 52·5 of carbon = carbonic oxide,	122·5 × 2400	294,000
Coal-gas	16 × 10,000	160,000
		454·000
Sum of heating power of water-gas and producer-gas		638,016

Heat in chimney-gases assumed to be of the same temperature as that when burning ordinary producer-gas.

779·7 × 377° × ·24 S. heat = 70,547 calories = 11·05 per cent.

These figures intimate that each 100 units of the three kinds of fuel burnt there is afforded by—

Coal, 83·93; ordinary producer-gas, 71·14; water-gas and its producer-gas, 78·80.

Of course, it will be readily understood that these results are not given as effective; but the loss, at the same description of work, say for raising steam, being considered identical, the relative value of each is assumed to be as above stated.

In cases, however, where an intense temperature is required in order to do the work in hand quickly, water-gas may be highly

advantageous. Some years ago I had an opportunity of seeing such an application at Essen in the welding of corrugated boiler tubes, and the work was admirably done.

A very important application of water-gas is mentioned, viz., for illuminating purposes. For this object the gas, itself destitute of any value in this direction, is made to heat filaments or stems of magnesia. These become so brightly incandescent as to vie, it is alleged, with the electric light, and, in consequence, water-gas is largely used for lighting in the United States, instead of coal-gas.

I have nothing to guide me in forming any trustworthy idea of the relative quantity of water-gas required in comparison with ordinary gas for a given amount of light. In the pamphlet already named, 9,000,000 tons of coal is given as the yearly consumption among gasworks in this country; and upon one occasion it was mentioned that a volume of coal-gas, which would require a 36-inch pipe for its transmission, might, in the event of water-gas being employed, be conveyed in one of 1¼-inch. If this be true, it means that water-gas supposing the friction to be the same in each case, which is far from being the fact, is at least 810 times as powerful as coal-gas, which is probably a mistake.

A good deal of stress is laid on the application of water-gas to the manufacture of open-hearth steel. I doubt whether, in an operation where a more moderate heat suffices, it can be worth while to seek to obtain one of a more intense character. At one steel-work with which I am concerned, the ingots were formerly heated in Siemens furnaces. These were abandoned, and ordinary coal-fed fires used in their place, and the saving of fuel effected by the change has been very marked. I should therefore be somewhat surprised if, with longer experience, there will be found any material advantage in using the water-gas in open-hearth steel furnaces.

It would appear from the figures used for representing the relative values of ordinary producer-gas, compared with water-gas and its accompanying producer-gas, that the sum of the latter gives a better result than the former, viz. 78·80, as against 71·14. The difficulty, however, will be, when the richer gas is wanted, to find a market or use for the poorer, which, it must be remembered, represents 71 per cent. of the heating power of the whole. Looking

The above quantity of water-gas is estimated to contain:—

Carbon	1619
Hydrogen	270
	1889 tons, valued at 43s. per ton.

If we take 1000 kilogrammes as being equal to one ton, the heat from this quantity of carbon, as it exists in the producer-gas, viz., as carbonic oxide, may be stated as representing (1000 × 5600 calories) 5,600,000 calories.

This quantity of heat could be obtained by the combustion of 700 kilogrammes of carbon (700 × 8000 being 5,600,000 calories). Now this carbon may probably be taken as equivalent to 800 kilogrammes of the small coke, and costing therefore about 8s., against 18s. 1¾d. for the same amount of heating power in the form of producer-gas.

The water-gas contains in 1000 parts:—

	Calories.
857 of carbon, which × by 5,600 =	4,799,200
143 of hydrogen ,, × by 32,480 =	4,633,200
	9,432,400

To produce this quantity of heat from pure carbon we should require $\frac{9,432,000}{8000}$ = 1179 kilogrammes of this substance. If we assume this quantity of carbon to represent 1350 kilogrammes of the small coke, this at 10s. amounts to 13s. 6d., which appears capable of affording the same quantity of heat as 857 of carbon and 143 of hydrogen, in the form of water-gas costing 43s.

From what has preceded, I have calculated that if a given quantity of heat, from coke burnt direct, costs 100; that from water-gas and producer-gases, according to Mr. Samson Fox's estimate of 2s. 8d. for gasification of the carbon, will be about 120, and according to Mr. Kupelwieser of 13s. 2d. about 200.

These calculations are my own, worked out upon the figures given by Mr. Kupelwieser, and they both tend to show how largely the cost of fuel was increased at Wilkowitz by the process of gasification. This gentleman then goes on to observe that, according to his experience, gas obtained from coal in good producers gives perfectly satisfactory results in open-hearth furnaces, and that in nearly all cases such furnaces are worked more economically with

ordinary producer- than with water-gas. At the same time he allows, that which I previously admitted, viz., that for some purposes water-gas may be profitably employed.

From another friend I learn that for each metre of water-gas, four metres of producer-gas have to be made. He would not consider it advisable to convert coal into gaseous fuel for the purpose of raising steam. The producer-gas obtained in manufacturing the water-gas is used in puddling furnaces and in heating large blocks of metal weighing as much as 50 tons. In the open-hearth steel furnaces a mixture of the two gases is employed, and, for steel intended for castings, this mode of treatment is considered very good, because the high temperature afforded by the water-gas, he says, enables the workmen to have the metal so fluid that it runs with ease into castings, however intricate.

DISCUSSION.

Mr. John Head said he was sure the members were very grateful to Sir Lowthian Bell for the able manner in which he had treated the subject, bringing it forward, as he had done, in a form which they could quite understand. A great deal of confusion had been created in the public mind by the recommendation of water-gas for various uses to which it was not applicable. It was assumed that, because water-gas would give a higher initial temperature of combustion, therefore it must be better than producer-gas for furnace purposes. That was not so. The real question was, what was the loss of heat in the chimney; and comparing the one gas with the other, the only difference between water-gas and producer-gas was, that the weight of the gases going up the chimney, at the same temperature in both cases, would be less in the case of water-gas than in the case of producer-gas. But, in considering that subject, they must not forget another point, namely, that in the combustion of water-gas a large quantity of steam was formed, and that the latent heat of this steam represented an amount of heat which could not be recovered in furnace work. He had made a calculation, based upon theoretical considerations, as to the value of water-gas as compared with producer-gas, and he had found that, when everything was taken into account, water-gas was about one-half per cent. better than producer-gas; or, in other words, 100 tons of carbon converted into producer-gas would yield the same result as 99½ tons converted into water-gas, and that was the only advantage that he could find. Then there was another point, namely, the question of cost. He had had no experience in working furnaces with water-gas, and was entirely dependent for his information on that subject upon the circulars which had been issued. He had made a calculation for Mr. Siemens, based on the figures given by the friends of water-gas, and he found that to melt two tons of steel, and to do a certain amount of other work, it would cost 18s. 3d. with water-gas, and only 10s. 6d. with producer-gas. The details of this calculation had been sent to

Mr. WILDY (Leeds Forge) said it was stated in the paper that from "15 to 30 per cent. of the heat of the coal was devoted to convert the coal into the gaseous form." From numerous records, the larger percentage was more correct for producer-gas; and from many analyses of producer-gas, even 60 per cent. was above the value of the heat-units in the gases compared with the heat-units in the fuel. The object of the conversion of the solid fuel into gaseous fuel was only partially stated by Sir Lowthian when he said: "This is done because, without this stimulus, the temperature obtained by burning coal in the ordinary way would not suffice for the object in view." A further and much more important object was to convert the fuel into a more manageable form, and that its employment might be made, wherever it was needed, under exact regulation, and with a minimum of labour and dirt. A temperature being obtainable with the gaseous fuel which was absolutely unattainable with solid fuel, proved that, where temperature was required, gaseous was the only form in which to use fuel, and where heat was required to be under control, gas offered the readiest means of producing and controlling the heat. The author again said: "For obvious reasons, when power is once generated, the sooner it is applied to the duty it is to perform the better. In like manner, that form of motion known as heat does its work most economically when the same rule is observed. Of course, it often happens that a sacrifice has to be made in order to meet the circumstances of particular cases." And, later on, he stated: "The natural laws to which I briefly alluded have been to some extent lost sight of in the recommendations advanced in favour of water-gas." Now, in the production of producer-gas, the heat necessary to volatilise the carbon was entirely lost; whereas, in making water-gas, it was this very waste of the ordinary producer-gas, coupled with a portion of the glowing carbon, which was employed to decompose the steam and produce water-gas. This was keeping very much in sight the earliest possible application of the heat which, without this application, was absolutely lost. Then, in Sir Lowthian's calculations of the comparative calorific effect of producer-gas, and the fuel from which it was made, he took credit for the whole of the carbon and hydrocarbons in the fuel, while it was well known that there was a large percentage of loss by conden-

works, while intending to be instructive, were most misleading. He had been in Witkowitz, and watched the producers there, and had received from the mouth of the engineer in charge very different statements from those now put forward by the author, as communicated to him by Mr. Kupelwieser. Some of those statements were published in the *Proceedings* of the Institute, and formed originally the subject-matter of a paper read before the Austrian Engineers' and Architects' Society. Other figures given by Mr. Kupelwieser were very interesting, as confirming in a marked degree the statements he had just made, that the loss in gasifying fuel with the water-gas producer was only 11·35 per cent., while he stated it to be 11·5 per cent., from their own experiments and calculations. The author stated in the course of his examination of the Witkowitz figures:—"It is, perhaps, worth comparing the assertion made in general terms in the pamphlet of the relative proportion of carbon received in the form of water-gas and as producer-gas:—

In the equation $H_2O + C$, we have $H_2 + CO$ for water-gas.
,, ,, $O_3 + C_3$, ,, $3\,CO$ for producer-gas.

The weight of the two equations of H is 2, and that of carbon 48, or 1 of H to 24 of carbon. Of oxidised carbon in the example just examined, when using raw coal, there was in the gases 44·8 of hydrogen and 1041·51 of carbon, or 23·24 of carbon for 1 of hydrogen. Now, the heat of 24 parts by weight of carbon burnt to carbonic oxide means 57,600 calories, which have been expended to obtain 1 part of hydrogen, which, when burnt to steam, is worth 29,400 calories—the loss being therefore, nearly 50 per cent. of the heat generated in order to obtain the single unit of hydrogen." It was here assumed that the whole object from first to last of making water-gas was to produce hydrogen—a fallacy, anything but philosophic. Taking the author's figures, what did they get? They got H_2 C_{48}, or H_1 to C_{24}. The 24 parts of carbon burnt to carbonic oxide meant 57,600 calories. Those 24 parts of carbon further burnt to carbonic acid equalled 134,400 calories, taking the hydrogen as 1, which, when burnt to steam was worth 29,400 calories, and adding this 29,400, brought the total to 163,800 calories. The 24 parts of carbon burnt to carbonic acid would

working at rather over three times the cost of Leeds. Including everything, interest, depreciation, wear and tear, &c., their cost at Leeds did not come out as one-third of that at Witkowitz. Sir Lowthian Bell, in claiming for solid fuel the utmost efficiency in use, mentioned the blast furnace, in which, having regard to the economic conditions to be observed, 90 per cent. of the full power was accounted for by the duty performed. That could only be accomplished by the efficient capture and employment of the top gases, which represented more than half the total heat-value of the fuel in the furnace, thereby converting the blast furnace into a veritable gas-producer, and using the best part of the fuel in heating the blast for the furnace, raising steam, &c.; and it was found that the higher the furnace, the better the gas. By his comparisons, Sir Lowthian Bell had actually proved the point which it was the object of the paper to discredit, namely, that in a gas-producer they got the utmost out of the fuel. Coming to the summarised results, and working on the assumed composition of the fuel, they got for coal a total possible of 720,000 calories. Coal burned in ordinary furnaces, without excess of air, minus loss in chimney, and assuming perfect combustion, which was seldom or never attained, 604,300 calories, equal to 83·9 per cent. For producer-gas, Sir Lowthian Bell took credit for too high a quantity of calories, because it could only yield about 70 per cent. of the heat-units in the fuel. Therefore, instead of having 614,000, they only got 401,000, or 55·8 per cent. For water-gas, pure gas from the gas-holder, they had 567,469, or 78 per cent. Sir Lowthian Bell further stated: "In cases, however, where an intense temperature is required in order to do the work in hand quickly, water-gas may be highly advantageous." That was one of the conditions of an open-hearth furnace; and if the melting down and refining of the charge could be accomplished in a period represented by a fraction of the time at present required, the result would be an increased annual turn-over on the capital invested; and where water-gas was employed to increase the combustible percentage, the results had been most satisfactory. He had with him some papers which had been sent him by a friend who was working water-gas, and he would shortly give them the results of working water-gas and producer-gas mixed in a furnace, which was the way advised for certain purposes, and

Mr. WILDY: Mixed to suit the circumstances entirely. They did not use the same amount of water-gas in reheating furnaces as they would use under any other circumstances. It was necessary to mix the gas to suit the work in hand. In the crucible furnace, using mixed gases, the make was from 5 to 6 charges of soft steel, consisting of 40 crucibles, each holding 78·5 lbs., per 24 hours. In gas puddling the production per 12 hours was 7 tons 16 cwt.; using coal in the gaseous form, 3 tons 4 cwt.; coal per ton of production, 8 cwt. 0 qrs. 8½ lbs. In the ordinary furnace the production was 2 tons; coal used as solid fuel, 1 ton 16 cwt.; coal per ton of production, 18 cwt., against 8 cwt. in the gas furnace, showing an economy of 55 per cent. With regard to steel melting, he had all the data as to the composition, cost, charges, and so forth, but the part that was most interesting was, that 30 charges at least per week were made, each charge taking from 4 to 5 hours.

Sir LOWTHIAN BELL asked what was the weight of the charge?

Mr. WILDY: 15 tons. The furnace would stand from 300 to 350 charges. There were less repairs required when using mixed gas than when using ordinary Siemens gas. The steel made was subjected to the tensile test of from 25 to 50 kilos. per square millimetre, or equal to 20 to 30 tons per square inch; elongation, 20 to 30 per cent., varying, of course, with the composition of the steel.

Mr. EDWARD RILEY asked if Mr. Wildy could give the weight of coal per ton of production?

Mr. WILDY said that in the steel-producing furnaces, using the ordinary old-fashioned Siemens producer, they used 13 cwt. to the ton; and with mixed gases they used from 8 to 9 cwt. It varied a little with the quality of the fuel. They used a lot of refuse, and that rather varied. They used commoner fuel altogether. There was one point in Sir Lowthian Bell's paper which, he thought, ought hardly to be passed without notice. It was that which stated that "a volume of coal-gas, which would require a 36-inch pipe for its transmission, might, in the event of water-gas being employed, be conveyed by one of 1¼

Lowthian Bell were untenable, even with regard to Moravia, and considerably more so with regard to England. But why, with the figures before him, with the results of English experience in water-gas production, figures obtained by actual working over extended periods by independent persons not connected in any way with the water-gas interest, Sir Lowthian Bell should go to Moravia for his data was incomprehensible. Under any circumstances, the figures from Moravia could not apply to English working; and though living there was remarkably cheap, from information that he had obtained, material was not. He had shown how unreliable were the figures upon which Sir Lowthian Bell had based his calculations of cost. The charges were three times higher than they would be in England. In charging fuel at 13s. 5¼d. which would cost about 6s., the statement that "coke at 36s. 5¾d. per ton would produce heat as cheaply as water-gas" fell to the ground. It should be divided at least by 2½. The concluding remarks of the paper showed, first, that gaseous fuel gave perfectly satisfactory results; and when Mr. Kupelwieser informed Sir Lowthian that in nearly all cases such furnaces were worked more economically with producer-gas than water-gas, he forgot the previous statement in the paper read before the Austrian Engineers' Society by an official engineer of the Witkowitz works, in which the following facts were stated:—First, coke of poor quality was used; second, 86·7 per cent. of the disposable quantity of heat was obtained in the gases; third, the gas was exceedingly well adapted for use on the open-hearth; fourth, when using water-gas it was found that the open-hearth could be worked at about one-half the cost involved when ordinary producer-gas was used, even though, for equal heat evolved, the cost of the water-gas stood in the proportion of 1·77 to 1·72 for producer-gas. All those particulars appeared in the *Journal of the Iron and Steel Institute*, vol. i., 1887, pages 368–9. The concluding paragraph of the author's paper summed up and confirmed the statements which he (Mr. Wildy) had made. As far as his experience went, the statements and calculations made in the paper demanded some explanation and correction. He desired, however, to thank the author, and the President and the Council, for giving him the opportunity of explaining his views on the matter.

kilos. per kilo. of fuel. The Cardiff coal cost five francs a ton more than the Scotch coal, but, allowing for this, it would be seen that there was no real saving with the gas-fired boilers. He could not himself be surprised that this was so, because he had always felt that if the incandescent mass of fuel were in the producer instead of in the boiler, there must necessarily be a considerable amount of radiant heat lost. Having taken a case favourable to the solid fuel, he would now take one where gas was essential. He referred to gas engines, which were now being made of considerable power, and as their efficiency as heat engines was known to be higher than that of steam engines, there was every probability that their use would be largely extended. These engines, of course, required gas, and here was a very profitable use for it. He could speak with the experience of engines that were developing an aggregate of about 3300 horse-power, and the general result was that, even with a small engine of about 10 horse-power, the fuel consumption was only about $1\frac{1}{8}$ lb. per indicated horse-power per hour. With larger engines it was about $1\frac{1}{4}$ lb., and at the paper-mills of Messrs. Spicer Brothers at Godalming, where there were Otto engines indicating a total of about 240 horse-power, Mr. Spicer told him, a short time since, that the average fuel consumption was only about 1 lb. per indicated horse-power per hour. He might mention, in connection with this subject, that at the Exhibition there were two engines well worth looking at; one was a four-cylinder engine of 100 horse-power, made by the Otto Company. The other engine was also for 100 horse-power, but had only one cylinder, and was the largest of its kind ever made. He had not seen it tested, so could not give its fuel consumption; but he might mention that an engine of the same type, giving 25 horse-power, consumed only $1\frac{1}{4}$ lb. per brake horse-power per hour. It was designed by Monsieur Delamarre Deboutville, and was made by Mr. Powell of Rouen. This engine would be found in the section for hydraulic machinery. Speaking generally, it might be, and doubtless was, the case, that theoretically they should expect to get a superior heating result from the solid fuel; but his contention was that in practice this was often not possible, and that for many purposes gaseous fuel was better and more economical,

WEDNESDAY, SEPTEMBER 25.

The proceedings of the Institute were resumed to-day—Sir JAMES KITSON, Bart., President, again occupying the chair.

The discussion on Sir Lowthian Bell's paper was continued.

Mr. SAMSON FOX said that, many times in the career of the Institute, he had found himself most heartily on the side of Sir Lowthian Bell; this time it so happened that they were not on the same side of the question. No doubt they both thought they were to a considerable extent right, but he was there to lay before the Institute a few facts which had come out of the actual working of the water-gas for nearly two years. He should have been only too pleased, before the paper was written, to give Sir Lowthian Bell the full opportunity of investigating what that apparatus had been doing and what it could do, and in that case he was sure that their opinions would have been nearer agreement. Everything depended for its value upon what it could produce, and the point to which the paper was mainly directed, was to show that water-gas could not be produced at such a price as to yield any better result than that which would have been obtained from using either solid fuel or producer-gas. He did not propose to deal with the question as to whether producer-gas or solid fuel had the advantage. He would leave the point whether gaseous fuel was better than solid fuel entirely to those who had had more to do with it than he had. However, with regard to water-gas, he thought he had had a fair opportunity of knowing what could be done with it in many ways. The paper, to his mind, was considerably wrong in its statement with reference to the cost of producing the gas; and they all knew that if they got wrong as to the cost of producing to the extent that these figures appeared to be, they were sure to arrive at wrong conclusions. The author had set down 12s. 2½d. as the cost of gasifying a ton of fuel, and he also stated that, in the pamphlet to which he referred, 2s. 8d. was given as the cost

Mr. Edward Riley wished to know how many of Mr. Fox's steel furnaces were at present working with water-gas?

Mr. Samson Fox said he had stated that they would have several furnaces at work in a very short time, which would be worked with mixed gas.

Mr. Edward Riley asked if there were none working with water-gas?

Mr. Samson Fox said not at present; but he had given data taken from furnaces that they had worked.

Mr. Edward Riley said that Mr. Fox had referred to the question of using water-gas for lighting private houses. Perhaps he would explain to the meeting how he got over the difficulty of employing in a private house so poisonous a gas as carbonic oxide, seeing that it was a gas which had no smell, whereas coal-gas had a very bad smell, but was not poisonous in the true sense of the word. An atmosphere containing 1½ or 2 per cent. of carbonic oxide was fatal to life in a very short time. Perhaps Mr. Fox would explain how he got over the difficulty that might arise from an escape of gas?

Mr. Samson Fox said he should be glad to do that. In the first place, it might not be generally known that the great bulk of the gas-tubing in houses was in a leaky state from end to end at the present time, and that something like 25 per cent. of the gas bill was due to leakage extant in all gas-fittings all over the country. If they made thoroughly tight gas-fittings, and introduced a little volatile liquid, that would tell the instant they had a leakage, they would then have no trouble or fear of injury arising from the use of a gas which was stated to be so poisonous.

Mr. Edward Riley: What is the percentage of the carbonic oxide in the gas?

Mr. Samson Fox: Perhaps 45 per cent.—equal volumes, or nearly so.

years, indeed, water-gas had been manufactured, but until now a practical application had not been attained. In 1872 he witnessed, in the north of France, experiments made by Mr. Tessié du Mottay. These experiments were duly reported in the *Comptes-rendus des Ingénieurs Civils* (*Transactions of the Civil Engineers of France*). Again, quite recently, before a meeting of civil engineers, the question of water-gas had been discussed under all its aspects, from the hygienic point of view, in that of the production of calorific agents, and in that of the production of sources of light. He would remind them that, at the outset, when experimenters wanted to make water-gas, they could not use coal. Therefore, he did not quite understand Mr. Wildy, when he stated that coal, coke-waste, and, in fact, all inferior fuels, could be indifferently used. But if they used coal, they must choose a dry and pure coal, as, if they used coke, it must be of a very pure quality; and, in that respect, he entirely concurred with the views of their friend Mr. Kupelwieser, who asserted on the previous day, "When you state that you use waste coke, I answer that I had to choose the best qualities of coke which I could find to make water-gas." Eighteen years ago water-gas was partially applied, and in order to obtain practical results, it was necessary, in 1872, at a time when coke was very dear in France, to buy it at 50 francs (£2) per ton to make water-gas. He was well aware that at that time their experience was limited to experiments, whilst to-day the object pursued was metallurgical applications, for which the gas was also used mixed with carbonic oxide. But, as had just been stated by Mr. Kupelwieser, inferior fuels might also be used; only, for the same production of gas, complicated apparatus were required, and, ultimately, the cost price was increased. With regard to the communication made by Sir Lowthian Bell, he believed it to be very admirable, as it possessed an unexceptionable quality, the eloquence of figures. It was quite true that every one was at liberty to interpret figures as he deemed proper. Mr. Wildy discussed them with a certain acrimony, and a vivacity which he himself should possibly have displayed, had he been called upon to defend his own interest. This was understood, but he thought it was difficult to convince one's opponents by bringing more or less vivacity into the discussion; it was experience alone which must support and finally

water gases were, or ought to be, free from carbon dioxide, which was not the case with blast-furnace gas. Some exception had been taken to the construction which had been put upon Mr. Fox's speech in regard to the size of the pipes required to convey water-gas for illuminating purposes. It was true that, in a speech made some months ago, Mr. Fox used the word "compression," but he never for a moment imagined that it could occur to any one to compress this gas so that a 1¼-inch pipe could carry as large a volume of it as a 36-inch pipe could do of ordinary coal-gas. For this it was estimated that a pressure of 600 lbs. on the square inch would be required. Surely Mr. Fox must have overlooked the power which would be required, the high temperature which would be generated, and the leakage of a very deadly gas under such a condition of things as those imagined by him. With regard to making cheap gas from gas-maker's breeze, where was the breeze to come from, after all the gasworks were suppressed, in order to make way for water-gas? Indeed, even now, as the President had just stated, breeze at Leeds, when washed, sold for 9s. a ton. Mr. Fox had called him to account for the estimated cost of converting solid into gaseous fuel. He had himself doubted the accuracy of the statement, which was Mr. Kupelwieser's, and not his; and, until Mr. Kupelwieser had explained the matter, he was in very great doubt as to whether it could cost anything like 12s. 2½d. to gasify a ton of coke in the manner proposed. But supposing it did not, Mr. Fox had himself given 2s. 8½d. per ton for doing the work; and as coal in ordinary times sold for 5s. per ton at the pit, that meant an addition of 50 per cent. to the price of coal. He could assure Mr. Fox that all that he wanted was to ascertain the simple truth. He believed, in the interests of that gentleman himself, the earlier this was ascertained the better. This observation was equally applicable to those who might contemplate laying out large sums of money in erecting plant which, in the end, might not realise the expectations formed of it. Mr. Kupelwieser had spoken with evident sincerity on the subject, and though he might not agree on every point with himself (Sir Lowthian Bell), on the whole there was a general agreement in the views expressed by both. He should be happy to avail himself of the offer made by Mr. Fox; and if he had erred in any of

other consumer of fuel. He thus obtained from every $31\frac{1}{4}$ tons of coal treated in the producers 1 ton of sulphate of ammonia, worth £12. However, $6\frac{1}{4}$ tons of coal were consumed in working up this sulphate, and, adding other expenses, a total cost of, say, £5 was obtained to set against the gain of £12, leaving nearly £7 profit on the sulphate. The tar-oils obtained Mond also utilised as fuel, and found that, though only obtaining 3 per cent. on the fuel gasified, yet those oils possess double the evaporative power of coal. The efficiency is thus brought up to 80 per cent. of that realised from the same fuel by hand-firing. At the price of 6s. per ton of coal, the profit on the sulphate, about £7, would represent about $\frac{140s. \times 20 \text{ cwt.}}{6s.}$, or 23 tons of coal. He ought to add that an allowance for wear and tear of plant was still necessary. Thus the depreciation of efficiency as against hand-firing was rather more than compensated for in the values of tar-oils and ammonia realised. If the gases were used hot from the generators, tar-oils and ammonia must be sacrificed. It should be added that, in hand-firing, of course all the nitrogen is lost, and carbon is lost in the ashes to some extent. One-half the nitrogen is gained by the process described by Mond, and the ashes only contained $3\frac{1}{2}$ per cent of carbon. But these considerations, though they were in the broadest sense indispensable, were still strictly supplementary to one of fuel-value; and Sir Lowthian Bell's conclusions were not one whit the less valuable for being strictly confined to a rigid comparison of the three fuel-materials on the basis of strict calorific efficiency. It may be of service and useful suggestiveness thus to touch upon another side of the question, and to regard its bearing upon the general subject. He thought, in the main, it could not be urged that Sir Lowthian Bell's assumption, that, in the production of producer- and water-gases, these gases were received at the regenerators *after being cooled*, was, comparatively speaking, an assumption wide of the mark, inasmuch as, in such cases, the gases usually passed, in the first instance, into and through rectangular flues composed of wrought boiler-plate; at all events through iron flues, exposed to the air, and hence to radiation and atmospheric cooling.* These flues

* In many cases it is not convenient, if possible, to annex producers so close to the furnaces that the gas shall be used hot.

in the second, by the two equations,

$$C + O = CO$$
$$CO + O = CO_2;$$

and in the third, by the three equations,

$$C + H_2O = CO + H_2$$
$$H_2 + O = H_2O$$
$$CO + O = CO_2;$$

but in each can the net result as to chemical change is identical, and the net heat development during that change is identical also.

If, instead of carbon, coal be employed, exactly the same end result would be attained in each case, any combustible matter present (other than carbon) producing the same amount of heat, no matter which way it be burnt, provided the combustion ultimately produced the same end products.

Although furnaces fired with water-gas did not possess any advantage over those fed with ordinary producer-gas, in the way of burning fuel so as to give rise to a larger development of heat on the whole, they nevertheless could be so worked as to produce a result impossible to attain with producer-gas. Suppose that a furnace is heated by gas regularly supplied by an ordinary producer so as to attain an approximately constant temperature. If, now, the producer be worked as a water-gas plant by alternately injecting air and steam, instead of blowing in air only, and if the rate of coal consumption be supposed to remain the same as before, the effect on the temperature of the furnace would be alternately to raise it above, and depress it below, the constant temperature previously attained. During the period when steam was blown in and water-gas produced, a hotter flame resulted from the formation of hydrogen; this extra heat, for the time being, was obtained at the expense of the sensible heat of the hot carbon in the producer, which was cooled owing to the absorption of heat during the change,

$$H_2O + C = H_2 + CO.$$

Later on, when air was blown in instead of steam, the producer-gas now formed was at a lower average temperature than it would have possessed had the mass of carbon not been cooled during

oxide. Ordinary coal-gas, containing 6 or 7 per cent. of that gas, was very dangerous on this score when even a small leak occurred, especially in a bedroom. In this case the peculiar odour of the gas usually gave some degree of warning that an escape existed. With comparatively scentless water-gas, containing several times as high a percentage of this deleterious constituent, the danger of poisoning would be greatly intensified.

Admitting that this objection was practically not of serious moment, there still remained another difficulty in the supply of water-gas for household purposes, &c.; viz., that, in order to produce it, something like three times as much carbon must be converted into producer-gas as was used for the water-gas, so that, as about 3 volumes of producer-gas contained as much carbon as 2 of water-gas, from four to five times as much producer-gas would necessarily be made, measured by volume, as was manufactured of water-gas. Hence, either the production of water-gas for town supply must be coupled with some other branch of industry in which this large quantity of producer-gas could be utilised, or else the producer-gas must be more or less wasted, and the cost of the water-gas correspondingly increased.

Sir Lowthian Bell has replied on the correspondence as follows:—At the Paris meeting of the Institute, where I had the honour of reading a paper on gaseous fuel, I pointed out some of the objections, in a calorific point of view, to water-gas as a substitute for coal, &c., in the solid form. Objections were strongly urged by gentlemen who differed from the views I had submitted for the consideration of those present. Our Secretary afterwards suggested the propriety of inviting opinions from certain chemists familiar with the practical use of coal and other varieties of fuel. Accordingly, Mr. Watson Smith, Professor Lunge, and Dr. C. R. Alder Wright have kindly replied to Mr. Jeans' request, and the result appears in the present volume. These have been sent to me, and I have been asked for a reply, should any be necessary. I should have preferred waiting until I had visited Mr. Fox's works, but as the opinions of these gentlemen virtually confirm my figures, I shall at once answer the minor objections they raise to what I said in my paper.

Mr. Watson Smith calls attention to my having omitted in

THE THOMSON ELECTRIC WELDING PROCESS.

By Mr. W. C. Fish, Boston, Mass., U.S.A.

Several years ago, at least in the history of the application of electricity to the arts, Professor Elihu Thomson, of Lynn, America, had occasion to deliver a lecture before the Franklin Institute in Philadelphia. In preparing certain electrical apparata for this lecture, Professor Thomson had the questionable misfortune of short-circuiting an induction coil, which, quite naturally, resulted in the fusion of the copper wire of the coil. If fusion could thus be produced accidentally, and if economical and practical, why should it not be intentionally produced and applied to the treatment of metals? And from this accident probably came the germ of thought which, to-day, extending and developing itself, gives to the arts the process of electric welding. During some time this idea lay dormant in the mind of Professor Thomson, who was busily engaged in the development of the Thomson-Houston system for electric lighting and transmission of power; but finally experimental machines were constructed, and these conclusively showed the excellence of the electric weld. The Thomson process was first publicly exhibited in New York in 1887, and since that time the development has been rapid in America, where it is recognised, more and more each day, as among the growing and important applications of electric energy.

The physical principles underlying this process are probably elementary to many of the audience, and have frequently been described in the technical journals.

The experimental law relating to the production of heat in a circuit through which an electric current flows, states that heat is produced at every portion of the circuit, first in direct proportion to the electrical resistance at any given point of the circuit, and secondly, in proportion to the square of the current strength. The resistance varies with the nature of the metal, the temperature, and inversely as the area of cross-section. Therefore, if an

approach of the pieces at exactly the proper temperature, and this done, to automatically shut off the current from the weld.

Another advantageous result of the simultaneous application of pressure and heat, is the slightly greater permissible range of temperature within which the weld can be made, and the consequent decrease of danger of burning the metal. Thus the welding temperature of certain classes of steel can be slightly reduced below that ascribed to the given metal in the smithy, by the substitution of pressure for temperature.

The following figures, taken at random, give a few results of tests made on the tensile strength of welds:—

Material.	Breaking Strength per square inch.	Position of Fracture.
	lbs.	
Wrought iron	53,110	1·7 inches from weld.
Cast steel	81,000	At weld.
Bessemer steel . . .	59,580	,, ,,
Copper (hard drawn) . .	31,830	,, ,,
,, ,, ,, . .	32,480	¾ inches from weld.
Brass	40,820	At weld.
,, ...	47,730	¾ inches from weld.
Steel and German-silver .	40,410	At weld.
Cast steel and wrought iron	52,130	3 inches from weld in the iron.
Brass and wrought iron .	33,550	At weld.

Generally speaking, in the welding of the ordinary commercial metals, after the characteristics of the metal and the knowledge of the requirements for its welding, have been gained by experimenting, a tensile strength, at the weld, of 90 per cent. of the strength of the unwelded metal is obtainable.

The time of welding varies with the conditions under which the weld is made. Thus, but only within limits, a comparatively large expenditure of electric energy for a short time is equivalent, for welding, to a smaller expenditure of energy during a longer time. The quicker the weld is made, however, the more economical it is, since there is less time for the loss of energy through the conduction and radiation of heat.

Determinations of the power and time required for welding give somewhat empirical results, owing to the indeterminable effects of conduction and radiation of heat, and other factors more or less changeable with different sizes and metals. For

It may be of interest to mention the possibility of electric riveting, which has already been accomplished, and is found to be a perfectly practicable process. The cold rivet is placed in the rivet-hole, electrically heated to the proper temperature, and then headed. The heating of a half-inch rivet, of two or three inches in length, would occupy probably about twenty or thirty seconds. As the plate itself becomes somewhat heated in the immediate vicinity of the rivet-hole, there is a partial weld made between the rivet-head and the plate.

This paper, though incompletely describing the fundamental principles of the art of electric welding, and scantily touching upon a few details of possible interest, gives but little idea of the questions of scientific interest which arise in the treatment of metals by electricity, or of the different uses to which the process either has been, or can be, applied. As an apology, the writer can only express the desire that any discussion which may follow will bring up those points which will lead to an increase of our knowledge of the various conditions and phenomena of heated metals, and their necessary treatment.

investigate this matter of electric welding. Mr. Fish was kind enough to give him very full explanations in London; and he had also seen some of the welding done at Glasgow, and at the Paris Exhibition he had had some "best Yorkshire" iron of his own welded, and he was taking it back to England to test. It appeared, from the engineering point of view, that the system would be most useful for large repetition work, where the number of articles to be welded would repay the cost, which must be considerable, of the clamps and special apparatus for holding and directing the pieces to be welded. He could not himself see that it could ever replace ordinary smith's work for occasional or miscellaneous welding, but for such purposes as welding angle-iron frames, or other articles which required costly labour and took considerable time, the system offered very great advantages indeed. Mr. Adamson had mentioned the welding of plates. He (Mr. Matheson) understood, from those gentlemen who had machines at work, that they had not yet succeeded in welding any width greater than three inches, and therefore it was not yet available for welding plates, or boiler rings, which no doubt would be a great boon to many of them. With regard to the power required, he thought they should take into account that the welding process occupied only from twenty to forty seconds, and, no doubt, a small engine with a heavy fly-wheel might concentrate for the few moments wanted a sufficient power. On the other hand, he thought the margin of power given between the electric horse-power and the mechanical horse-power was not sufficient. He did not think that any one accustomed to electrical machines would venture to have a 100 horse-power steam-engine if he wanted 85 electrical horse-power. He must have a greater margin than that, although in that matter they were open to correction by electricians. One other point which appeared to be rather astonishing was, that wires, when welded, should give, as he understood, 85 per cent. of the strength of the wire. A wire got so much of its strength from having been drawn, that it was very difficult to see how a weld could transmit more than the strength of the original wire rod. In other words, if a steel rod which would take 30 tons to the inch was drawn, and became wire which would carry 100 tons to the inch, one would have thought that the weld would only have transmitted the strength

an enormous gain. The members would be interested to know that a cable message had been received that morning from the Thomson Electrical Welding Company, inviting them to visit their works in Massachusetts next year. He hoped that the members would be able to accompany him on that visit.

A vote of thanks having been passed to Mr. Fish by acclamation, the following paper was read:—

ON ALLOYS OF IRON AND SILICON.

By R. A. HADFIELD, Sheffield.

The alloying of elements, other than carbon, with iron is a comparatively new field, and possesses special interest, not only to those concerned and engaged in the treatment of metals, but also to those who study the physical properties of substances. As the properties and nature of alloys of carbon and iron are fairly well understood, it is hardly necessary to consider them here, and in order to narrow down the considerations dealt with in this paper to a practicable limit, attention will be confined solely to alloys or mixtures of which metallic iron and silicon form the principal constituents.

An investigation of the properties of manganese steel, *i.e.*, an alloy of iron and manganese, was placed before this Institute by the author some twelve months ago, and its physical properties have been fairly well determined, as compared with alloys of iron with other elements. This was the more practicable owing to the fact that the manufacture of "cast iron" alloys of manganese, that is, ferro-manganese, had been for some time past in a very advanced state. In other words, the cheap production of the alloys known as rich ferro-manganese—a material containing 80 per cent. of manganese and 5 per cent. to 7 per cent. of carbon, the residue being iron—has enabled experiments to be readily carried out by further alloying such rich manganese products with pure iron.

Mr. Turner's paper read at the British Association Meeting, Bath, last year, described experiments with steel containing from ·10 per cent. to ·50 per cent. of silicon, and the details were fully given in the "Proceedings" of the Institute. The writer was asked by Mr. Turner and the British Association Committee to investigate the effect of higher percentages of silicon, and he thought that the results of his inquiries might also be of interest to the Institute.

could be produced. If so, without doubt considerable employment could be found for them in metallurgical industry.

TABLE I.

	Analysis per Cent.				Remarks.
	Carbon.		Silicon.	Manganese.	
	Graphite.	Combined.			
Analyses of *spiegel* and *ferro-manganese*, showing the gradual increase of carbon as the manganese increases	...	4·27	·110	8·11	Sulphur and phosphorus practically absent, remainder being iron.
		4·78	·52	19·74	
		5·63	·42	41·82	
		6·53	·97	80·04	
		7·20	·14	80·04	
Analyses of *special manganese*, showing that if the silicon becomes high the carbon diminishes very considerably	...	3·56	4·90	23·90	Ditto.
		2·56	4·20	50·00	
Analyses of *silicon-spiegel* or *silicide of manganese*	·33	1·85	10·74	19·64	Ditto.
	·67	·98	12·60	19·74	
	·90	·30	15·94	24·36	
Analyses of *ferro-silicon*	2·35	·05	8·77	2·42	Ditto.
	1·85	·06	11·20	2·78	
	1·20	·23	14·00	1·95	
	·55	·11	17·80	1·07	

These analyses are from a paper by Mr. Holgate, Assoc. R.S.M., Darwen, on "The Manufacture of Ferro-Manganese and Ferro-Silicon in the Blast Furnace."

Alloys or compounds of iron, carbon, and silicon, non-malleable in their nature, and coming under the term "cast iron," have been thoroughly investigated in this country by Mr. T. Turner of Birmingham, and the results have been placed before this Institute, so that it is unnecessary to do more than touch upon the matter here. Great credit is due to this investigator for the lengthy and valuable researches he has made in the direction indicated, as also to Mr. Keep, of Detroit, U.S.A., who has lately presented interesting papers on the same subject to the American Institute of Mining Engineers. Mr. Keep sums up so well the general results of all investigations up to date, that it may be well to briefly mention them, especially as some of the remarks apply, to some extent, to the malleable compounds or alloys of iron and silicon now being described. Both Mr. Keep and Mr. Turner find that white carbonaceous cast iron, which would invariably

In metallurgical literature, but little reliable information is to be found as to the effect of silicon upon iron. Mr. Howe in his excellent work on "The Metallurgy of Steel" gives an excellent *résumé* of what has appeared. Some fourteen years ago, in America, good results were promised by a process which was to use "Codorus, or silicon ore," as it was termed. This was to dephosphorise or neutralise the phosphorus in the metal under treatment. Only a few years back, the writer had reason to investigate this matter in America, but found that this so-called puddled silicon iron or silicon steel contained no silicon. The whole matter was happily summarised by the well-known metallurgist, A. L. Holley of America, who said, or rather sang, of it:—

"There was an old man of Codorus,
Who said he took out the phosphorus,
So the iron he puddled, and with chemicals muddled,
But the puddling took out the phosphorus."

Referring now to the consideration of silicon alloyed with the metal iron, the common belief has been that steel which has to be used in its forged state should contain practically none, or as small an amount as possible. Any quantity exceeding ·10 per cent., or up to ·20 per cent. at most, has been considered to be highly injurious. "Give a dog a bad name" is well illustrated in the present case, as will be seen from the results and tests given. At any rate, it may be safely said that silicon has been blamed in a somewhat hasty manner. This blame may be well deserved in alloys of carbon, silicon, and iron, as such alloys, as regards ductility, have no doubt proved unreliable and of little value, but the blame has been put at the door of silicon, whereas it is now proved that silicon, alloyed with iron, provided carbon is absent, or only present in small amounts, gives good tests as to toughness and malleability. It will be seen that 1½ or even 2 per cent. may be present, and yet the material may possess 25 to 30 per cent. elongation; whereas the same percentage of carbon, alloyed with iron, would give a product barely malleable and one possessing but little elongation under tensile stress. Whilst, therefore, the common belief that alloys of carbon, silicon, and iron are brittle, or even dangerous, is quite correct, the cause is not due to silicon only, but to the combination of

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The annealed flat bending pieces, half-an-inch wide by one-fourth of an inch thick, gave good results, specimens A., B., C., and D. (·24 per cent. to 2·18 per cent. Si) bending double cold without fracture, more like soft steel, and after being bent double the pieces were flattened close together cold, without showing signs of fracture. Specimen E. (2·67 per cent. Si) also bent double cold, but broke in the radius with the last blow. F. (3·46 per cent. Si) was much stiffer, bending only to a right angle. G. and H. (4·49 per cent. and 5·53 per cent.) would not bend at all, and were exceedingly brittle. These bending tests were confirmed by Mr. Turner's experiments with bars of the same size. Up to D specimen the samples bent to an angle of 180°, with one-eighth of an inch radius.

Pieces from the bars used for bending tests were also tested for weldability, but entirely without success. The writer's experience has always been that silicon is quite fatal to welding, notwithstanding that the contrary might be expected from the fact that silica is of such material assistance in welding wrought iron.

As regards water-quenching or hardening, samples A., B., C., and D. (·24 per cent. to 2·18 per cent. Si) were unaffected, *i.e.* unhardened, by even the highest heat. Even if plunged at welding heat into water made specially cold, no hardening beyond a surface stiffening took place, nor did their toughness seem impaired by this treatment. Specimen E. (2·67 per cent. Si) was heated to an ordinary yellow heat, and plunged into cold water at about 70° Fahr. This piece was much stiffened, but only broke on being bent double. Another piece of the same material, heated to a welding heat, and plunged into water at about 52°, also proved very stiff, and only broke when bent double. Sample F. (3·46 per cent. Si) was only stiffened by being water-quenched at a welding heat. It was just as brittle as before, and had not hardened, being easily touched by a file. In this respect, therefore, *i.e.*, as to being toughened by water-quenching, this material differs from manganese steel. The heating did not cause much alteration in fracture, the crystallisation being still open and coarse. H. (5·53 per cent.) was quenched both at ordinary heat and at a welding heat, and although the surface was skin-hardened, upon being fractured it was easily filed.

TABLE III.—*continued.*

Compression Tests.

Series.	Test Bar Mark.	Analysis per Cent. Carbon.	Silicon.	Manganese.	Load applied in Tons per Square Inch.	Reduction in Length produced by Load.	Diameter Increased to
E	206	·20	2·67	·25		Before being Tested. 1·009.	·7979.
No. 206 gave no indication of set by pointer.					10	1·009	·7979
					20	1·008	·8000
					30	·9915	·808
					50	·901	·850
					100	·622	1·0345

Series.	Test Bar Mark.	Analysis per Cent. Carbon.	Silicon.	Manganese.	Load applied in Tons per Square Inch.	Reduction in Length produced by Load.	Diameter Increased to
F	207	·21	3·46	·29		Before being Tested. 1·009.	·7985.
No. 207. No indication of set by pointer.					10	1·009	·7985
					20	1·009	·795
					30	1·0045	·8000
					100	·6455	1·0115

Series.	Test Bar Mark.	Analysis per Cent. Carbon.	Silicon.	Manganese.	Load applied in Tons per Square Inch.	Reduction in Length produced by Load.	Diameter Increased to
G	208	·25	4·49	·36		Before being Tested. 1·008.	·7985.
No. 208. No indication of set by pointer. Gave several loud reports as pressure was increased up to 50 tons, and then ceased.					10	1·008	·7985
					20	1·008	·7985
					30	1·0045	·8000
					40	·9895	·806
					100	·683	1·003

In order to test this steel in the shape of wire, samples E. (2·67 per cent. Si) and G. (4·49 per cent. Si) were reduced to rods, and Messrs. Shipman & Co., of Sheffield, kindly undertook

TABLE IV.—*Non-Malleable Ferro-Alloys.*

Malleable Ferro-Alloys.

Malleable compounds of iron with other elements so far experimented upon (including carbon, silicon, sulphur, phosphorus, chromium, tungsten, aluminium, and nickel) are strongly susceptible to magnetization.

Alloys of manganese and iron, however, form an exception to this. As is now well known, in manganese steel, as soon as the manganese exceeds 8 or 9 per cent., the material is only attracted when in a finely divided state such as drillings or powder, and with further increase of manganese even this slight susceptibility disappears. The same fact is noticed as regards the non-malleable compounds of iron and manganese. Alloys of iron, nickel, and manganese are also not susceptible.

As in the forged, so also in the cast material, when the silicon exceeds about 2 per cent., and the peculiar crystallisation noticed in the samples exhibited commences, neither annealing nor water-quenching seems to have any effect in changing the structure.

It is well known that considerable difficulty is experienced in dissolving drillings of ferro-silicon ; so tedious is the process, that recourse is usually had to the sodium carbonate process. This is not requisite with silicon steel, which requires only the ordinary hydrochloric acid method. The silica residue is very clean and free from iron.

A considerable number of estimations have proved that the silicon is very uniform and homogeneous in this steel. Analyses taken from different parts of the same ingot and bar give results very similar to each other. No traces of graphite are noticed, the carbon being always present in the combined form. If the material analysed is in the form of drillings, they keep their shape, the iron being dissolved out.

Experiments have been made with this steel in comparison with other material as regards its corrosion. Table V. gives the time of immersion in the sulphuric acid, and the loss.

In conclusion, the author wishes it to be understood that he does not claim that there is any field for the employment of such an alloy, or high silicon steel, as that here described. This paper is presented only for the purpose of scientific interest, and in order to place on record the actual effect of the metalloid silicon on iron. Silicon cannot take the place of carbon ; the latter has always the advantage of being more easily applied, and of producing a material more suited to the various requirements of users of steel.

It is also clearly proved by these experiments that silicon, unlike carbon, does not confer upon iron the property of becoming hardened when water-quenched.

TABLE V.—*Corrosion Experiments.*

		Percentage of Silicon.	Strength of Acid (H_2So_4).	Length of Immersion.	Loss per Cent.	Remarks.
Silicon steel (C.) . .	Bar	1·60	50 per cent.	21 days	6·32	
,, ,, (E.) . .	,,	2·67	,,	,,	3·32	
,, ,, (G.) . .	,,	4·49	,,	,,	4·29	

		Silicon.	Atmosphere.	21 at	Increase in Weight.
Silicon steel (C.) . .	Bar	1·60	20 634 grams.	20·644 grams.	10· grams.

The following Table gives the specific gravities of the silicon steel, as well as that of ferro-silicon:—

TABLE VI.

		Percentage of Silicon.	Specific Gravity.	Remarks.
Silicon steel (E.) . .	Ingot	2·67	7·38	
" " " . .	Wire 20 B.W.G.	2·67	7·88	
" " (G.) . .	Ingot	4·49	7·54	
Ferro-silicon . . .	...	5·00	7·00	
" . . .	...	8·00	6·943	
" . . .	...	16·00	5·303	Doubtful.
Ordinary grey cast iron	...	...	7·10	

TABLE VII.—*Samples of the Alloys of Iron and Silicon Exhibited in order to Illustrate this Paper.*

SECTION I.—Samples of silicon steel in the cast state, containing from ·24 per cent. to 8·83 per cent. of silicon.

SECTION II.—Samples of silicon steel in the forged state, containing from ·24 per cent. to 5·53 per cent. of silicon.

SECTION III.—Test bars as mentioned in Table II.

SECTION IV.—Bending pieces given in Table II.

SECTION V.—Compression pieces given in Table III.

SECTION VI.—Samples of ferro-alloys to illustrate magnetic properties.

SECTION VII.—Silicon steel wire 2·67 per cent. Si, 20 B.W.G.

Sample of ferro-silicon containing 16 per cent. silicon, yet honeycombed.

Silica from silicon steel.

Other samples.

Correspondence.

Mr. Alex. Pourcel remarks that they should be grateful to Mr. Hadfield for following up with so much perseverance his very interesting studies, which had already led him to such remarkable discoveries relative to manganese steel.

The few facts which Mr. Pourcel had to mention in support of Mr. Hadfield's statements referring to his experiments on the alloys of iron and silicon were abstracted from a paper which he communicated eleven years ago, on the 7th of September 1878, to *L'Industrie Minérale.*

He then attempted to free silicon from its bad repute, based upon no well-established grounds, of having the most pernicious influence on forged steels, as well as on their mechanical qualities.

In the works of Montluçon-St.-Jacques, under Mr. Mussy's management, before the year 1875, steel had been prepared with 2½ per cent of silicon, and a small percentage of carbon; it had been hammered, and was used for sheet iron and wire without any difficulty. Mr. Hadfield had confirmed this fact by numerous experiments fifteen years later.

The property of silicon of transforming combined carbon into the graphitic state was studied by Captain Caron, Director of the Artillery Laboratory of Saint-Thomas d'Aquin, in 1862, at least twenty-seven years ago. Captain Caron made a report as to the result of his researches to the Academy of Sciences. He was of opinion that the use of silicon should be prohibited in the manufacture of tool-steels, not because that alloy rendered the latter more brittle, but because, in course of time, and under the influence of repeated reheatings, it diminished their hardening properties. A cutting tool was blunted by use, and was restored to its original condition by repeated forging, before it was thrown away; and silicon had the property of displacing at a red heat the hardening carbon; therefore, the hardening property of a steel containing a certain percentage of silicon would be affected by several reheatings.

This criticism did not apply to steels destined for large forg-

The general publication of those facts, and their collection into a connected system, required many years of experience and study. Mr. Hadfield had quoted the names of those experimenters whose work had contributed to throw light on that most interesting question. Mr. Pourcel would add that Mr. Hadfield's own work would not be the least distinguished.

Mr. H. A. BRUSTLEIN (Unieux), having been obliged to quit Paris before Mr. Hadfield's paper came on for discussion, was unable to take part in its consideration, as he would have liked to do. The knowledge of the influence of silicon on steel had, however, been advanced by investigations of older date than those cited by Mr. Hadfield. Among these he would notably refer to the works of Mr. Wenzel Mrázek, Professor at the School of Mines at Pribram, in Bohemia, who made a series of investigations on the alloys of—

1. Iron and silicon.
2. Iron, carbon, and silicon.
3. Iron, silicon, carbon, and manganese.

The remarkable work of Mr. Mrázek was worthy of being translated into English. It had already been published in the *Berg-und-Hüttenmänn. Jahrbuch der K. K. Bergkademie zu Pribram, Jahrgang XX.* From that period the researches of Mr. Mrázek had given some useful hints to those who were practically engaged in working upon this matter. Although silicon in steel was considered by some as a friend, and by others as an enemy, it was still an enigma to the man of science, and the practical steel manufacturer was not always permitted by his circumstances to furnish all the elements that would be likely to contribute to the elucidation of the problem.

Mr. W. J. KEEP remarks that the author had referred to Mr. King's diagram showing that a decrease of silicon changed grey iron to white. As contributing similar information, he referred, in an article about to be published by the American Institute of Mining Engineers, entitled "Phosphorus in Cast Iron," to engravings in Table II. showing the change of grain, where, owing

substantially alike, and yet each series showed results exactly contrary to those reported in his papers on the action of silicon before the American Institute, *i.e.*, each cast decreased in strength until 2·75 Si, when it was 12 per cent. weaker than at first, but increased in the next three casts, until, at the last, the strength was 55 per cent. greater than the first cast. This was an example of the way that chemical combination, or, more likely, mechanical structure, due to some unexplained cause, often surprised us in practice.

Mr. HARRY S. FLEMING (of the Cameron Iron and Coal Company, Emporium, Pa.) states that in regard to the re-melt, viz., silicon 1·25 to 5·55, he found that, using Drown's method of solution of drillings in dilute nitric acid, evaporating with dilute sulphuric acid and solution in water, and filtering and igniting to burn off the carbon, the resultant silica retained perfectly the shape of the drillings, was pure white, and completely volatilised by hydrofluoric acid. These silica skeleton drillings were examined under a microscope, and found to be a mass of minute crystals, but they were too small to show the form of crystallisation. Mr. Fleming thinks it possible that by re-melting an iron the silicon will gradually leave the combined form and assume the graphitic one, or be oxidised to silica, at least partially. Is there any proof that silicon, as such, is contained in steel, or in any metal which has been exposed to strong oxidising influences? In some experiments which he had been making, he had found only traces of silicon, while he had found as high as 1·23 per cent. of silica in some Bessemer steels.

Mr. T. TURNER (Mason College, Birmingham) regretted that he was unable to be present at the reading of the interesting and important paper presented by Mr. R. A. Hadfield. He had, however, been fortunate in seeing a number of the samples while the experiments were in progress, and in obtaining specimens for preservation in the collection at Mason College. The result of Mr. Hadfield's researches, while confirming a number of his (Mr. Turner's) observations, and very greatly extending our knowledge, showed, at the same time, the great importance of

of hardening when it was heated and afterwards rapidly cooled. This point had been considered doubtful for some time past, though perhaps the general opinion had been in the opposite direction, due probably to the fact that when carbon and silicon occurred together in a sample of steel, the metal could sometimes be more readily water-hardened than if carbon only were present. Probably the greatest difference in the conclusions arrived at as a result of the several series of experiments was in connection with the influence of silicon on the weldability of the metal. The specimens examined by Mr. Hadfield were all deficient in this respect, while those prepared by himself (Mr. Turner) all welded well, except when, owing to a deficiency of manganese, the metal was red-short. No special care was taken by the smith in producing these welds, the specimens being given to him in the ordinary way, to be treated in exactly the same manner as the hundreds of other tests he would perform in the course of the year. The bar was then nicked and broken across the weld, and the fracture carefully examined. The tests were performed under the superintendence of Mr. Harbord, who has had special experience of such work, while all the samples were preserved, and had been recently re-examined. So that he (Mr. Turner) could not think that the weldability of ingot iron in any way suffered from the presence of silicon. It should be mentioned, however, that the highest amount of silicon added was only 0·5 per cent., and that the original metal itself welded perfectly.

The value of a series of experiments so complete and carefully conducted as those of Mr. Hadfield could scarcely be over-estimated, and it was much to be desired that those interested in the manufacture of iron and steel might soon be furnished with information with regard to all the other important elements as complete and as trustworthy as we now possessed in the cases of manganese and silicon.

Mr. Charles Wood remarks that he listened with much attention to the paper read by Mr. Hadfield at the Paris meeting, and regretted that the time did not allow of a more extended discussion. He thought Mr. Hadfield had not given sufficient credit to the paper read by himself (Mr. Wood) at the Glasgow meet-

had shown that the commonest iron, such as mottled and white, could be reduced to any degree of softness by the proper mixture of silicon iron; and an iron-founder, by following this rule, and studying analyses of the irons at his command, could now produce in his cupola the exact quality of iron most suitable to his castings, instead of, as hitherto, depending upon special and expensive brands, which were often very uncertain in producing what was required, although the fracture might be all that was desired, whilst the only explanation was to be found by analysis. The fact that the firm that he had the honour to represent (Messrs. Wilson, Pease, & Co.) had made, and continued to make, many thousands of tons of silicon iron, which, prior to this discovery, was put back into the blast furnace, was a sufficient proof that both the theory and the practice were sound, and that iron-founders were daily leaving the old practice for the new.

Mr. Wood would merely add that, however interesting the information collected together by Mr. Hadfield—for which they were greatly indebted—and however valuable the experiments made by Mr. Turner and Mr. Keep, he found nothing new, or of any practical value to the ironfounder, which had not been already published. At the same time, these experiments, along with those of M. Gautier, had so completely confirmed the scientific rule and discovery first announced and laid before the Iron and Steel Institute at the Glasgow meeting, that there could not be any further doubt about it. And this had been more than once acknowledged in the able addresses of the late President of the Institute.

Mr. R. A. Hadfield, in reply to the correspondence, said he was glad to read the interesting contributions from American friends, Messrs. Keep and Fleming.

He much regretted the omission of reference to Messrs. Wood's and Stead's work in connection with the application of silicon to cast iron. His (Mr. Hadfield's) paper was, however, written principally as regards alloys of iron and silicon, not alloys of cast iron and silicon. The paper only referred to the latter when bearing upon the points under consideration. It was in no way intended as help to an ironfounder—Messrs. Turner, Wood, Stead,

Gautier, and Keep had done that—but it did deal with alloys of iron and silicon in such a way as to clearly establish the influence of the metalloid silicon upon the metal iron, a question hitherto in doubt.

M. Osmond, of Paris, was giving much attention to experiments upon samples of this steel furnished by the author, and important discoveries had been made which, no doubt, M. Osmond will shortly be able to lay before the Iron and Steel Institute.

The following paper was then read:—

A NEW FORM OF SIEMENS FURNACE, ARRANGED TO RECOVER WASTE GASES AS WELL AS WASTE HEAT.

By JOHN HEAD, F.G.S., M. Inst. C.E., London,

AND

P. POUFF, Ingénieur des Arts et Manufactures, Nevers.

Before referring to the special subject of this communication, and in order that it may be the better understood, it is necessary to call attention very briefly to the great advance which has been made in heating and metallurgical operations, as the result of the labours of the late Sir William Siemens and of Mr. Frederick Siemens in connection with the regenerative gas furnace.

The first idea of applying the regenerative principle for industrial purposes appears to have occurred to the mind of the Rev. Robert Stirling in 1817, who, with his brother, James Stirling, invented a regenerative air engine, since bearing their name, which worked economically at the Dundee Foundry, and was found to be quite as efficient as the steam-engines of that day. They also foresaw the possibility of applying the regenerative principle to metallurgical furnaces. A more complete form of furnace of the same kind was devised in 1837 by Mr. J. Slater. According to this arrangement, as well as in the earlier form proposed by the Stirlings, only the air supplied to the furnace was to be heated, and solid fuel was intended to be employed. Neither of these proposals, however, led to any practical result, so that they can only be looked upon as mere philosophical ideas or suggestions. The same remark applies also to the later proposal of Mr. R. Laming, who, in 1847, took out a patent for a regenerative furnace embodying the then novel principle of first converting solid fuel into gas, to be burnt in a furnace in combination with air heated by means of the waste products of combustion. This was a further step in advance in furnace construction; but as Laming's invention was proposed for heating gas retorts, and coke was in consequence the fuel intended to be

J in the usual manner of working regenerative gas furnaces. An auxiliary steam jet is provided for the purpose of supplying atmospheric air to start the producer, when the furnace is first heated up.

The new form of regenerative gas furnace has been applied in this country to the heating and welding of iron, to which uses its application is being extended in England and abroad, whilst furnaces are in course of construction to apply it for puddling iron, and for copper and steel melting. Altogether ten furnaces for these purposes are in course of construction, in addition to two furnaces already at work for heating iron.

The first furnace of this kind was constructed at the Pather Iron and Steel Company's Works at Wishaw for welding iron, and much credit is due to the proprietors for having had the enterprise and public spirit to make the first application of this improved regenerative gas-furnace. The working has been eminently satisfactory from the commencement. The success of this first application of the furnace proves the correctness of the principle upon which it is constructed, and the means adopted for carrying it out.

The results of working during the past six months have shown an average saving of 5 per cent. in waste on the weight of the iron heated, and a saving of upwards of two-thirds of the weight of coal used, and a greater money-saving, owing to the inferior quality of the fuel employed as compared with that used in their other furnaces fired with solid fuel. From the total saving thus realised should, however, be deducted the cost of raising steam, for which purpose the waste heat of the old furnaces is utilised. Allowing for separate boilers, the saving effected by the use of the new system in a furnace heating eight tons of iron per shift, is nearly eighteen tons of coal per week, and the money-saving in iron and coal exceeds £1000 per annum.

This new furnace has also been recently applied for heating billets by the United Horse Shoe Company, of London, and in this case the results are quite as satisfactory, or even better, than those just given, as is shown by the accompanying table:—

regenerative gas furnace, of the same productive capacity, with separate gas producers and gas regenerators, and the space occupied below ground is also considerably reduced.

A saving of labour attends the employment of the new furnace, as, owing to the producer being connected with the furnace, the same men can attend to both, and the labour of firing is reduced in proportion to the reduced consumption of fuel.

In conclusion, the following advantages may be claimed for the new furnace as compared with solid-fuel furnaces used for heating and welding iron, viz. :—

A saving in fuel, amounting to, say, two-thirds in weight, and after allowing for raising steam in separate boilers, this saving is fully equal to 5 cwt. of coal per ton of iron heated.

A reduction in the waste of iron equal to 5 per cent. upon the weight of metal heated.

A saving in labour and repairs which will probably compensate for the extra cost of the new furnace.

Taking a furnace to heat 10 tons of iron per shift, or 110 tons per week, the following calculation gives the money saving realised by the adoption of the new furnace :—

110 tons iron at 5 cwt. per ton = 27½ coals saved at 6s. . .	£8	5	0
110 „ „ at 5 per cent. = 5½ tons iron at £4	22	0	0
Being . .	£30	5	0

per week, or say, £1500 per annum.

It may be added that the authors had hoped that the application of this furnace to the attainment of high temperatures, such as are required for steel melting, might have been included in the paper, but the furnaces building for this purpose are not yet completed. Should they, however, be working when the paper is read, information with regard to them will be given in the discussion.

DISCUSSION.

The PRESIDENT said it would be a great advantage to have the discussion on the paper postponed until the London meeting, because they would then, probably, have before them the experience of the ten or twelve furnaces now building. It occurred to him to remark that the proposed arrangement appeared to solve the difficulty, and to remove the objection of Sir Lowthian Bell as to the cooling of the gases. They had the direct application of the gases to the material, and it was an admission, to a certain extent, that there was a loss in the cooling of the gases. The arrangement appeared to him to be a most admirable one. The only question he wished to ask Mr. Head was, whether he had any difficulty in passing the flame through the whole body of the furnace? It appeared as if there would be a difficulty in the flame reaching the doors.

Mr. HEAD said that there was no difficulty experienced in getting the heat to the doors in the horse-shoe flame furnace shown by the diagrams.

The PRESIDENT said the subject was one of great interest. He was sure that they would all be satisfied, from the reputation of Messrs. Siemens and the authority with which they treated the subject of furnaces, that the matter was one that ought to receive the careful attention of those who had large masses of iron to heat. He had great pleasure in proposing that the thanks of the meeting be given to Mr. Head and to Mr. Pouff for their paper.

The motion was unanimously adopted, and the following paper was next read:—

THE ROBERT-BESSEMER STEEL PROCESS.

By F. LYNWOOD GARRISON, PHILADELPHIA.

THE history of this modification of this ordinary Bessemer process dates back to about the year 1884, when what was then known as the Walrand-Delattre converter was put into practical operation at the Stenay Works, Meuse, France. This converter having already been described,* it will be sufficient to simply call attention to the above fact.

The converter at present used at Stenay, and known as the Robert converter, is shown in figs. 1 and 2. It is used either with an acid or basic lining, as desired.

It has a distinctly elliptical shape, having a flat surface P in which the tuyeres "a" are always placed on the same plane parallel to the axis XX of the apparatus. It has a swinging movement on its trunnions X′X′, supported by suitable bearings. This movement can be imparted by means of any suitable mechanism; for instance, by that clearly shown in the drawings, and the effect is that the range of tuyeres can be simultaneously disengaged from the metal bath.

The tuyeres, placed horizontally, as described, form, with the flat surface P, unequal angles varying with the shape of the transverse section of the apparatus, with a view to impart a rotary motion to the bath, which brings all parts of the metal bath successively under the oxydising influence of the blast. This movement causes a regular and methodical rotation of the bath, so as to prevent too prolonged a period of decarburization of each portion of the metal.

As soon as the metal is run into the converter, it is tilted up until the metal comes to the level of the tuyeres, and the blast is turned on (fig. 3).

By the action of the blast through the range of tuyeres inclined at different angles a rotary motion is gradually imparted.

When this movement, which is indicated by the spiral move-

* *Iron Age*, vol. xl., No. 10; *Journal*, No. II., 1887, p. 314.

that the apparatus must be further raised, until it arrives at a position where, if the blast were shut off, the tuyeres would be covered by about 1½ in. to 2 ins. of metal.

It is easy to understand that by tilting the converter more or less, and by manipulating the blast valve, the operator can at will change the volume and pressure of the blast to correspond with the requirements of the different phases of the operation.

It is of great advantage to be able to control the pressure of the blast so as to regulate it at the different periods of the operation, and in proportion to the quantity of the charge in the converter.

The resistance to the blast may be varied by tilting the converter more or less on one or the other side, and as the tuyeres have all the same height of metal to support, the pressure on each tuyere is consequently the same.

It is obvious that the blast pressure required is much less than in the ordinary Bessemer converter. A converter which has the tuyeres at the bottom will require a much higher pressure of blast than one which has its tuyeres at the sides.

In an ordinary Bessemer converter, the height of the iron above the tuyeres is the entire depth of the metal, and in the "Robert" converter it is only about from 10 to 15 centimetres; the result is, that an economy of blast force is obtained for the same quantity of iron.

The average pressure of the blast is about 4 lbs., the aim being to have just sufficient pressure to keep the slag "*out of the metal,*" and to produce the rotation of the bath. In no case should the blast penetrate deeply into the bath; it must only impinge upon its surface.

The first period of the blow lasts from seven to eight minutes, the second from three to four. At the end of the second period the flame disappears, and it might be supposed that the carbon has been eliminated. The blow, however, is continued during a third period, lasting from one and a half to two minutes, in which the flame reappears, and is of considerable size. As a rule the blows are quiet. As soon as the flame drops, after this third period, the converter is turned down and about one per cent. of seventy per cent. ferro-manganese added. The converter is then allowed to stand about ten

zontal surface; above this are placed two layers of bricks, laid flat. The thickness of the sand and the bricks must be calculated so that the lining of the bottom is at least 10 ins. thick, and its upper surface 11½ ins. below a plane passing through the axis of the tuyeres. When the bottom is completed the lining of the sides is constructed.

Suppose we are dealing with a converter calculated to contain from 1000 lbs. to 3600 lbs. of pig iron. The mould is made in the following manner:—On the line AB (fig. 6), which represents the interior flat surface, a perpendicular DE is erected. On this perpendicular, from the point D, a distance DC is marked equal to 7¾ ins. From the point C as a centre, with a radius of 15½ ins., a circumference FKG is described, which represents the shape of the interior of the converter.

At the part corresponding to the mouth, the lining gradually diminishes until there is a thickness of one brick only.

If the converter is designed for a greater capacity than 3600 lbs., the interior dimensions of the lining will be increased without increasing too much the distance of the point K; that is to say, in proportion as the transverse section of the area increases the proportion $\frac{DK}{2CK}$ diminishes, and the curve CKF becomes semi-elliptical.

Fig. 7 shows the form and dimensions of the bricks suitable for a 1-ton apparatus; the bricks of the form A are for the curved portion of the lining; the bricks B are for all the other parts, the bottom, flat surface, &c.; 10 ins. is given as the length of the bricks A, but they can be made of a length equal to the thickness of the curved portion of the lining. The mortar used for the joints in acid linings must be very refractory. The cost of a brick lining is rather high. A skilled and careful workman is required to make it, otherwise the joints are not made close enough, and escapes occur. If clay sufficiently refractory, and capable of binding well when rammed, can be obtained, it is preferable to make the lining of composition. Its cost is much less than that of a brick lining, its construction is more rapid, it does not require special workmen, and it is more homogeneous.

We commence by lining the bottom to the desired thickness,

disposed in the same way. Care must be taken to preserve the respective inclinations whilst ramming.

When the tuyeres are nearly worn out, the operation can be continued by doing the small necessary repairs every four or five blows. The apparatus is placed in the position shown at fig. 13, balls of mortar are thrown on the tuyeres, and they are beaten down with an iron peel or trowel. Holes are pierced in this mortar by means of a mandril of the diameter of the tuyeres, and it is allowed to dry for from fifteen to twenty minutes. With a 1-ton apparatus, and the arrangement of tuyeres above indicated, experience has proved that the best blast pressure on the tuyeres is from 3 to 4 lbs. per square inch. Below 3 lbs. operations are very lengthy and difficult to manage. Above 4 lbs. they are colder, last almost as long, and the waste is greater.

Whatever the pressure one may have at disposal, a regulating valve is necessary. When the capacity of the apparatus is increased, the number of tuyeres must be increased, but the blast pressure need not be appreciably higher.

The analysis of the pig iron used at the Paris works, 150 Rue Oberkampf, is as follows:—

	Per cent.
Carbon	3·50
Silicon	2·00
Manganese	1·00
Sulphur	0·05
Phosphorus	0·05

The resulting steel had a range of from 0·07 to 0·30 per cent. carbon, from 1·60 to 3·90 per cent. silicon, and about 1·00 per cent. manganese.

It is claimed for the process that the composition of the resulting steel can be regulated to a nicety. It is very doubtful, however, if it possesses any advantages over the ordinary Bessemer process in this particular.

Pig iron having a high percentage of silicon naturally causes a high temperature in the operation, but it has the disadvantage of materially increasing the waste. On the other hand, it is inadvisable to reduce the percentage below 1·4 in the pig iron at the cupola.

— the percentage of silicon is low, in order to obtain a high

This thick mixture is much more dense than the thin; its composition in weight is about—

Tar	15
Dolomite	85
	100

The lime used must be free from moisture, and, like the dolomite, contain as little silica as possible. The composition of the resulting basic slag is about as follows:—

	Per cent.
Silica	
Lime	25·80
Magnesia	trace
Oxide of iron	trace
Phosphoric acid	16·00
Sulphur	0·17
Manganese	2·80

The amount of phosphoric acid varies from 15 per cent. to 25 per cent.

The following tables of tests of "Robert" steel were supplied by the Robert Steel and Iron Company (Limited), London. They are claimed to be average working results obtained at the Blaenavon works in England, and at the Stenay works in France.

BLAENAVON WORKS, TESTING-HOUSE.—*December* 14, 1888.

Report on Tensile Tests of Basic Steel.

Marks and Numbers.	Materials.	Size of Specimen.			Maximum Strain.		Breaking Strain.		Elongation.		Contraction of Area.		Remarks.
		Length.	Diam.	Area.	On Piece.	Per sq. in.	On Piece.	Per sq. in.	Stretched to	Per cent.	Diam. at point of Fracture.	Per cent.	
		Ins.	Ins.		Tons.	Tons.	Tons.	Tons.	Ins.		In.		
1	Robert tin bar	2	·565	·25	6·25	25·00	5·12	20·5	2 25/32	39·00	3/8	59·84	Samples of tin bar made of Robert basic steel.
2	,, ,,	,,	,,	,,	6·25	25·00	5·35	21·42	2 13/16	40·62	11/32	62·88	,, ,,
3	,, ,,	,,	,,	,,	6·47	25·89	5·35	21·42	2 3/4	37·5	11/32	62·88	,, ,,
4	,, ,,	,,	,,	,,	6·25	25·00	5·12	20·5	2 13/16	40·62	11/32	62·88	,, ,,
5	,, ,,	,,	,,	,,	6·02	24·10	5·12	20·5	2 13/16	40·62	11/32	62·88	,, ,,
6	,, ,,	,,	,,	,,	6·25	25·00	5·12	20·5	2 25/32	39·00	3/8	59·84	,, ,,
1	Robert billets .	,,	,,	,,	6·69	26·78	5·35	21·42	2 5/8	31·25	3/8	59·84	Samples of billets made of Robert basic steel.
2	,, ,,	,,	,,	,,	6·47	25·89	5·35	21·42	2 23/32	35·31	3/8	59·84	,, ,,

BLAENAVON WORKS, TESTING-HOUSE.—*July* 15, 1889.

Report on Tensile Tests of Basic Steel.

Numbers.	Materials.	Size of Specimen.			Maximum Strain.	Breaking Strain.	Elongation.		Contraction of Area.	
		Length.	Diameter.	Area.	Per sq. inch.	Per sq. inch.	Stretched to	Per cent.	Diameter at point of Fracture.	Per cent.
		Ins.		Sq. in.	Tons.	Tons.	Ins.		In.	
1	Robert steel	2	Flat $1 \times \frac{3}{8}$	·375	25·00	22·61	$2\frac{45}{64}$	35·31	$\frac{3}{4} \times \frac{3}{16}$	62·40
2	" "	"	Round ·565	·25	24·10	20·53	$2\frac{27}{32}$	42·18	$\frac{11}{32}$	62·88
3	" "	"	"	·25	27·67	25·00	$2\frac{3}{4}$	37·50	$\frac{3}{8}$	55·84
4	" "	"	"	·25	27·67	24·10	$2\frac{3}{4}$	37·50	$\frac{3}{8}$	55·84
5	" "	"	"	·25	28·92	25·00	$2\frac{25}{32}$	39·06	$\frac{11}{32}$	62·88
6	" "	"	Flat $\frac{3}{4} \times \frac{1}{2}$	·375	25·82	22·61	$2\frac{27}{32}$	42·18	$\frac{7}{16} \times \frac{1}{4}$	70·83
7	" "	"	"	·375	23·80	19·07	$2\frac{13}{16}$	40·62	$\frac{7}{16} \times \frac{7}{32}$	74·48
		...	...	...	26·14	22·70	...	39·19	...	63·59

D. JONES.

Average Analysis of the above Samples.

Results of Experiments to Ascertain the Elastic and Ultimate Tensile Strength, &c., of Seven Pieces of Basic Steel Bar Manufactured by the "Robert" Process.

Test No.	Description.	Original: Size.	Original: Area.	Stress: Elastic, per sq. inch.	Stress: Ultimate, per sq. inch.	Ratio of Elastic to Ultimate.	Contraction of Area at Fracture.	Stress per square inch of Fractured Area.	Extension, Set in 10 inches: At 30,000 lbs. per sq. in.	At 40,000 lbs. per sq. in.	At 50,000 lbs. per sq. in.	Ultimate.	Appearance of Fracture: Silky.	Granular.
	Sq. ins.	Inches.	Sq. ins.	Lbs. Tons.	Lbs. Tons.	Per cent.	Per cent.	Lbs.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
892	2	turned 1·597	2·000	32,400	55,690	58·1	58·3	133,709	0·00	3·21	8·92	27·4	80	20
890	do.	do.	do.	30,700	55,045	55·7	56·7	127,124	0·00	3·68	9·64	27·9	95	5
888	do.	do.	do.	28,300	50,865	55·6	59·9	127,003	0·82	5·59	18·9	28·8	95	5
894	do.	do.	do.	28,100	49,810	56·4	68·2	156,635	0·96	6·20	...	35·3	100	0
			Mean	29,875 = 13·3	52,852 = 23·6	56·4	60·8	136,118	0·89	4·67	12·49	29·8	93	7
898	2 × 2½	shaped ·75 × ·50	·375	41,500	57,590	72·0	66·6	172,768	0·00	0·00	7·81	24·8	Silky	...
897	do.	·75 × ·50	·375	35,700	56,910	62·7	70·6	194,009	0·00	1·87	8·19	26·4	do.	...
896	do.	·75 × ·48	·360	31,800	51,520	61·7	75·0	206,077	0·00	5·32	14·3	27·3	do.	...
			Mean	36,333 = 16·1	55,340 = 24·6	65·5	70·7	190,951	0·00	3·59	10·10	26·2		

David Kirkaldy & Son.

99 Southwark Street, London, S.E.,
28th *May* 1889.

The following are analyses of basic Robert steel made at the Blaenavon works:—

	1.	2.	3.	4.
Carbon	·112	·122	·102	·084
Silicon	·027	·022	·035	·100
Sulphur	·136	·048	·032	trace
Phosphorus	·080	·052	·049	·076
Manganese	·258	·411	·307	trace

Silicon in No. 4 has been repeated with result Si = ·093 per cent.

The following tables show (pp. 279–280) the total amounts of material used, and the resulting productions of the *acid* and *basic* converters at the Stenay works for the months of May and June 1889. The figures have been converted into English lbs.

Results of Experiments with Steel Castings made by the "Robert" Process—Acid Steel (Stenay).

Average Chemical Analysis of 24 *Samples of various Steel Castings.*

Silicon.	Manganese.	Carbon.
0·144	1·077	0·250

Average Tensile Test of the above 24 *Samples.*

Tensile Strain per Square Inch.	Elongation.
31·3 tons.	16·3 per cent.

It is claimed by the inventor that, by the acid process, steel of any desired quality can be produced, and especially for making castings of the highest quality of soundness and finish; and that by the basic process a peculiarly soft, ductile metal is produced, equal in all respects to irons of the highest class manufactured in South Yorkshire and Staffordshire.

ACID CONVERTER.

Loss . . . . 12·6 per cent.
To the 1000 { Coke . . 310
{ Iron . . 1142

May 1889.

Consumption in Eleven Days' Work = 124 Blows.														Production.			
Coke.	Lime-stone.	Rids. I.	Rids. III.	Solvey I.	Solvey II.	Solvey III.	Ber-guette.	Old moulds.	Spiegel.	Ferro-Mang.	Ferro-Silicon.	Scrap.	Total.	Ingots.	Castings.	Scrap.	Total.
Lbs. 816,046	Lbs. 8,184	Lbs. 11,330	Lbs. 48,620	Lbs. 770	Lbs. 29,238	Lbs. 29,150	Lbs. 82,720	Lbs. 35,992	Lbs. 2,398	Lbs. 4,164	Lbs. 6,769	Lbs. 13,398	Lbs. 264,550	Lbs. 12,452	Lbs. 214,368	Lbs. 4,169	Lbs. 230,989

ACID CONVERTER.

Loss . . . . 12·8 per cent.
To the 1000 { Coke . . 292
{ Iron . . 1146

June 1889.

Consumption in Eleven Days' Work = 110 Blows.														Production.			
Coke.	Lime-stone.	Rids. I.	Rids. III.	Solvey I.	Solvey II.	Solvey III.	Ber-guette.	Old moulds.	Spiegel.	Ferro-Mang.	Ferro-Silicon.	Scrap.	Total.	Ingots.	Castings.	Scrap.	Total.
Lbs. 67,443	Lbs. 7,260	Lbs. 70,070	Lbs. 87,736	Lbs. 14,520	Lbs. 16,940	Lbs. 11,220	Lbs. 2,200	Lbs. 2,200	Lbs. 5,852	Lbs. 3,555	Lbs. 6,063	Lbs. 11,770	Lbs. 232,126	Lbs. 3,190	Lbs. 194,381	Lbs. 4,917	Lbs. 202,488

BASIC CONVERTER.

Loss . . . . 16 per cent.
To the 1000 { Coke . . 217
Iron . . 1193

May 1889.

Consumption in Fourteen Days' Work = 229 Blows.										Production.			
Coke.	Lime-stone.	Lime.	Grey Iron.	White Iron.	Spiegel.	Scrap.	Esch.	Ferro-Mang.	Total.	Ingots.	Castings.	Scrap.	Total.
Lbs. 106,189	Lbs. 14,982	Lbs. 66,528	Lbs. 427,350	Lbs. 2,640	Lbs. 1,045	Lbs. 6,776	Lbs. 46,970	Lbs. 6,230	Lbs. 491,011	Lbs. 411,917	Lbs. ...	Lbs. 740	Lbs. 412,731

BASIC CONVERTER.

Loss . . . . 16·5 per cent.
To the 1000 { Coke . . 234
Iron . . 1200

June 1889.

Consumption in Thirteen Days' Work = 200 Blows.										Production.			
Coke.	Lime-stone.	Lime.	Grey Iron.	White Iron.	White Iron.	Scrap.	Esch.	Ferro-Mang.	Total.	Ingots.	Castings.	Scrap.	Total.
Lbs. 101,965	Lbs. 12,134	Lbs. 59,642	Lbs. 296,010	Lbs. 96,030	Lbs. 7,920	Lbs. 7,282	Lbs. 31,680	Lbs. 5,042	Lbs. 448,964	Lbs. 366,102	Lbs. ...	Lbs. 5,016	Lbs. 371,118

When I mentioned to Sir Henry Bessemer that excellent material had been produced in this converter, he replied that if you blow the proper amount of air, in any manner you please, through good pig iron, you will get a good steel. Whether such is a fact or not, we should not condemn the Robert converter *in toto* until it has failed to produce, under the same conditions, a *better* result when tried side by side with an ordinary Bessemer converter, or else failed to produce an equal result with a greater economy. May it not be possible that M. Robert has produced with somewhat similar means what Sir Henry Bessemer failed to do years ago?

The criticism that in the Robert converter, as in all small Bessemer converters, the blows are too cold, does not seem to be substantiated. At the Paris works, I timed the interval from the end of the blow until all the metal had been cast by means of small ladles to be from twenty-five to thirty minutes. As far as I could observe, the metal at the last ladleful was nearly as fluid as at the first.

I greatly regret that I have not had the time nor the opportunities to give this subject a more careful study, but it is to be hoped that, as many of the members will see the converters themselves, points which have been omitted, or but barely mentioned, in this paper will be brought out in the discussion.

"To the owners and managers of the works to be visited at Creusot, the Loire, Longwy, the Nord, and the Pas-de-Calais, for throwing open their works for the inspection of members, and for the hospitality they have offered, on the occasion of the meeting in Paris.

"To the London, Chatham, and Dover Railway Company, the London, Brighton, and South Coast Railway Company, the South-Eastern Railway Company, the Chemin de fer de l'Ouest, and the Chemin de fer du Nord, for the exceptional facilities which they have afforded to the members of the Iron and Steel Institute on the occasion of their general meeting in Paris.

"To Mr. Henry Chapman, for the complete, satisfactory, and successful arrangements which, as Honorary Local Secretary, he has made, in connection with the *Société des Ingénieurs Civils*, for the present meeting."

The resolutions were adopted by acclamation.

Mr. Adamson said that they would be neglecting an important duty if they did not, before closing, give their best thanks to their worthy President for the manner in which he had presided over the meeting, and the great work that he had performed so efficiently, even when he had been absent from the meetings, in perfecting the organisation, which had resulted in so pleasant a gathering. He begged to propose "that the best thanks of the Iron and Steel Institute be, and are hereby, tendered to the President, for the judicious and courteous manner in which he has presided over the Paris meeting." It was unnecessary that he should add anything to enforce the President's suitability for the position to which he had been appointed by the members of the Institute. Personally, he rejoiced to think that they had so good a President, and he hoped that he would have equally good health, and would feel equally at home, when they met him, as he hoped most of them would do, next year in America.

Mr. S. R. Platt had great pleasure in seconding Mr. Adamson's proposal, which required no further words from him. They all knew the President's great ability, and it must certainly be a

gratification to him to see so many members attending the Paris meeting.

The motion was carried by acclamation.

The PRESIDENT said he was much obliged to the members for having passed the vote of thanks so cordially. He was proud to think that the meetings they had held had been, perhaps, the most successful meetings of the Institute. As their numbers increased, so their influence would extend, and the usefulness of their proceedings would be more widely felt. If he had been able so far to serve the members satisfactorily, he hoped that he might be permitted to continue to do so with equal approbation until the end of his term.

VISITS AND EXCURSIONS.

INSPECTION OF THE EIFFEL TOWER.

ON the morning of Thursday, the 26th of September, the members of the Institute assembled at the Eiffel Tower (south pier), where they were met by M. Eiffel and by a number of members of the *Société des Ingénieurs Civils.* The party were carried to the top of the third platform (905 feet in height), where they spent a considerable time in examining the arrangements of the tower, and in admiring the far-reaching prospect that lay around in all directions. Fortunately the weather on the occasion was all that could be desired.

At twelve o'clock the members were entertained at luncheon at the Restaurant Brebant, on the first platform, by the *Société des Ingénieurs Civils.* M. Eiffel presided. More than 300 sat down, and the spacious restaurant was filled to overflowing.

After lunch, Sir James Kitson, President of the Institute, proposed the health of M. Eiffel in appropriate terms, and congratulated him upon his success in the construction of so graceful a structure as the tower that bears his name.

M. Eiffel responded as follows :—

MESSIEURS,—Je ne veux pas renouveler les toasts qui ont été portés hier, avec tant de dignité et de courtoisie, par votre Président, Sir James Kitson. Je tiens seulement à vous dire que je suis heureux d'avoir, au nom de la Société des Ingénieurs Civils à vous recevoir ici et d'avoir pu vous faire visiter en détail, cette Tour qui est l'une des plus grandes constructions métalliques qui aient été faites. Nous savons en effet que vous excellez dans l'art de ces constructions oú vous avez débuté si glorieusement par le Pont Britannia avec Stephenson et où vous poursuivez votre brillante carrière avec le Pont du Forth auquel les noms de MM. Fowler et Baker resteront à jamais attachés.

Bien d'autres constructions, notamment la galerie des machines dont

items on the printed programme which had been prepared for the guidance of the party were as under:—

8.30 A.M.—Inspection of the rolling-mills.
10 „ Visit to the forge, with the steam-hammer of 100 tons and the press of 6000 tons.
10.45 „ Visit to the artillery shops.
11.15 „ Visit to the polygon, where a 24-cm. gun was to be fired.
11.45 „ Proceed to the offices of the firm.
12 noon.—*Déjeûner.*
2.15 P.M.—Resume inspection of the works.
2.30 „ Visit the engineering shops.
3.45 „ Visit the steelworks, passing *en route* the blast-furnaces.
4.30 „ Proceed to the chief offices for refreshments.
5.00 „ Leave by train for Dijon.

The above programme was adhered to as closely as possible, and M. Schneider and his chief managers and engineers, who remained with the party throughout the day, were indefatigable in answering all questions, and affording all information likely to be useful or interesting to their guests.

The visitors observed in the rolling-mills all the operations that are usual to such an establishment, except, perhaps, the manufacture of rails, which are not now produced at Creusot to any extent. The chief manufactures were bars, channels, deck plates for protected cruisers, and wire rods. There were many different trains of rolls in operation, and alongside of these were ordinary and mechanical puddling furnaces. Three high rolls were employed in the rolling of H iron. The bars used for this purpose were delivered on to a floor which was crossed by several slides, in which pitched chains carrying lugs were worked. These chains were set in motion when a bar was delivered, and the lugs projecting above the floor carried the bar to one side of the space provided for it. For the heavier sections of bars, the mills employed had rising and falling tables at each side, which rose or fell as required to deliver the bloom to the rolls. These movable tables are worked by steam cylinders, and serve to reduce considerably the labour of the men. For the rolling of deck plates a large and powerful reversing mill is employed, capable of rolling ingots up to 11 or 12 tons. An 11-ton ingot was passed through this mill in the presence of the visitors, and reduced to a plate, intended for the deck of a Chilian cruiser, which measured 14 metres in length, by 1·56 metre in width, and 50 millimetres thick.

Medal, which had been awarded to M. Schneider by the Council of the Institute, and was to have been presented to that gentleman at Paris, had he not, by public duties, been prevented from attending.

Sir Lowthian Bell, Bart., F.R.S., Past-President of the Institute, on behalf, and at the special request, of the Council, made the presentation in the absence of the President, who had arranged to proceed with the party visiting the works in the district of the Loire. Sir Lowthian, in the course of his remarks, referred to the long connection that had existed between M. Schneider and himself, and to the enterprise and ability with which the great works at Creusot had always been conducted. Among other special qualities required for conducting such a gigantic establishment as that which constituted one of the objects of their visit, was the ability to select a suitable staff for carrying out the instructions of the commander-in-chief. Sir Lowthian referred to his long acquaintance with M. Barba and other officers entrusted with the direction of the Company's affairs, and was able from personal observation to speak with great confidence of their high capacity and intelligence. Those qualities had enabled M. Schneider and his distinguished father to establish there, almost in the centre of France, and far removed from the sea, the most important works of their kind in that great and important country. M. Schneider had shown his appreciation of the value of new processes and improvements, such as it was the special business and aim of the Iron and Steel Institute to promote, in many ways. He had, at a comparatively early date, taken up the manufacture of Bessemer steel, and, more recently, he had carried out the basic processes in a satisfactory manner. The connection of Creusot with the early introduction of the steam-hammer was very well known; and so also with other mechanical and metallurgical advances. Sir Lowthian had no doubt that the members of the Institute would derive both pleasure and profit from their visit to Le Creusot on that occasion, and he thanked M. Schneider on their behalf for the considerate and liberal hospitality with which they had been received. Sir Lowthian concluded by proposing the health of M. Schneider and his family.

M. Schneider, on receiving the medal from the hands of Sir Lowthian, made an appropriate reply. He expressed, first of all, his satisfaction at seeing so many members of the Institute at Le Creusot, although he would have been better pleased if many more had come. He deeply felt the honour which had been conferred upon him by the Council of the Institute in awarding to him the blue riband of the

30 per cent. of iron, the blast being heated to 750° C., at a pressure of 18 centimetres of mercury.

At the works of Messrs. Saintignon & Co. there are two blast-furnaces with open tops, with Cowper stoves 18 metres high by 6·40 metres in diameter, the blast being heated to from 750° to 800° C. MM. Saintignon & Co. are the inventors of an improved pyrometer actuated by means of a current of water for measuring the temperature of the blast at the tuyeres. Each furnace is provided with four copper tuyeres, each 160 millimetres in diameter. The coke employed comes from Belgium; it contains 13 per cent. ash. About 1230 kilos. per ton of No. 3 iron produced are required when working with a burden containing 29½ per cent of iron.

At the works of *La Société des Hauts-fourneaux de la Chiers* there are two large blast-furnaces of 6·50 and 7 metres in diameter, respectively, at the top of the bosh, and 19·50 metres in height. They are together capable of producing 200 tons of foundry pig, or 250 tons of forge pig, per 24 hours. Each is furnished with four Cowper-Siemens stoves of 17·50 metres in height, two steam lifts, two vertical blowing engines, system Cockerill, with two steam cylinders and one air cylinder of 3 metres in diameter and 2·40 metres stroke. There are nine boilers with double tubes, heated by the waste gases from the furnaces. The ores are obtained from the deposit of Mont-de-Chat, and from the mines of Laroux-Longlaville and La Madeleine.

After leaving the works at Senelle, the party again took the train, and arrived, at 4.30, at Mont-St.-Martin, where the blast-furnaces, converters, and rolling-mills of the Longwy Steelworks were inspected. This large establishment consists of six blast-furnaces of 300 to 480 cubic metres capacity, three on each side of the railway; three basic-lined converters, each of 15 tons capacity, capable of producing 400 tons of ingots per day, and powerful rolling-mills for blooms, rails, billets, sheets, and wire rod. The basic linings of the converters last for 160 to 175 operations, the plugs going from 16 to 25 blows. The dolomite is shrunk in three cupolas, with natural draught, the firing lasting 8 days, the whole charge of the cupola being drawn at one time. The Thomas pig employed in the manufacture of the basic steel is taken molten from the blast-furnace to the converter, and contains from 1·8 to 2 per cent. of manganese, 2 per cent. of phosphorus, from 0·35 to 0·40 per cent. silicon, and 0·05 per cent. sulphur. Manganiferous ores from Nassau are employed in its manufacture. The slag is ground, and sold as a fertiliser, for thirty-six francs per ton at the works. A

Dudelange, used in the production of Thomas pig, the samples having been dried at 100° C.:—

	Luxembourg Ores.			Manganese Ore.
	Minettes Grises.	Minettes Jaunes.	Minettes Rouges.	Mineral de Nassau.
Thickness of bed in metres	3 metres	2-2·20 m.	1 metre	...
Silica	6·62	7·22	10·78	10·82
Ferric oxide	49·73	58·50	58·20	35·28
Alumina	5·68	6·69	5·96	7·84
Lime	15·10	8·00	6·45	1·46
Magnesia	0·83	0·85	0·79	0·86
Phosphoric acid	1·79-1·90	2·11	2·10	0·19
Volatile matter	20·76	17·16	15·70	10·12
Metallic iron	34·81	40·95	40·74	MnO_2 28·51 } *
Phosphorus	0·78	0·92	0·91	MnO 5·31 }

The annual production of steel ingots at these works is about 110,000 tons.

The ordinary quality of steel produced has about the following composition:—Carbon, ·06 to ·07 per cent.; phosphorus, ·07 to ·08 per cent.; manganese, ·3 to ·35 per cent. Extra soft material is also produced in which the phosphorus is about ·03 to ·04 per cent.

The after-blow lasts three minutes. 3·5 kilos. of 60 per cent. ferro are added per ton of pig converted.

The basic slag produced has the curious characteristic, which is not met with in other basic slags, of rapidly falling to a flakey powder on cooling. Its composition is:—

Silica	5·85
Protoxide of iron	14·06
Peroxide of iron	1·47
Protoxide of manganese	5·58
Alumina	trace
Lime	53·50
Magnesia	2·95
Phosphoric acid	16·69
Sulphur	0·33

The basic linings are rammed, and go 150 blows; the plugs go 22 blows. There are 100 holes in the plugs, 18 mm. diameter at the top, and 20 mm. diameter at the bottom; formerly they only used 80 holes, but they find that with 100 the oxidation is less.

After inspecting the steelworks and rolling-mills, the party re-entered the special train, and were taken by it close to the château of

* Equals 22·18 per cent. metallic manganese.

M. Emile Metz at Dommeldange, where they were hospitably entertained at lunch by M. and Madame Metz.

The party subsequently returned to Longwy, where they finally broke up.

Excursion to Maubeuge.

A small party of members of the Institute left Paris on Thursday, the 26th, in order to visit some of the works in the Nord. The party was received at Maubeuge by M. Jambille, director-general of the Maubeuge Company, by M. Dumont, *fils*, representing the *Société des Forges de Gustave Dumont et Cie;* by M. Dufer, director of the *Société Anonyme de la fabrique de fer de Maubeuge;* by MM. Victor and Armand Dumont of the Espérance Works; by MM. Jaumain and Freson of the Providence Works; and by MM. Armand Sépulchre of Alnoyl; Morel Sépulchre of Tilleul; Felix Sépulchre of Vezin-Aulnoye, and others.

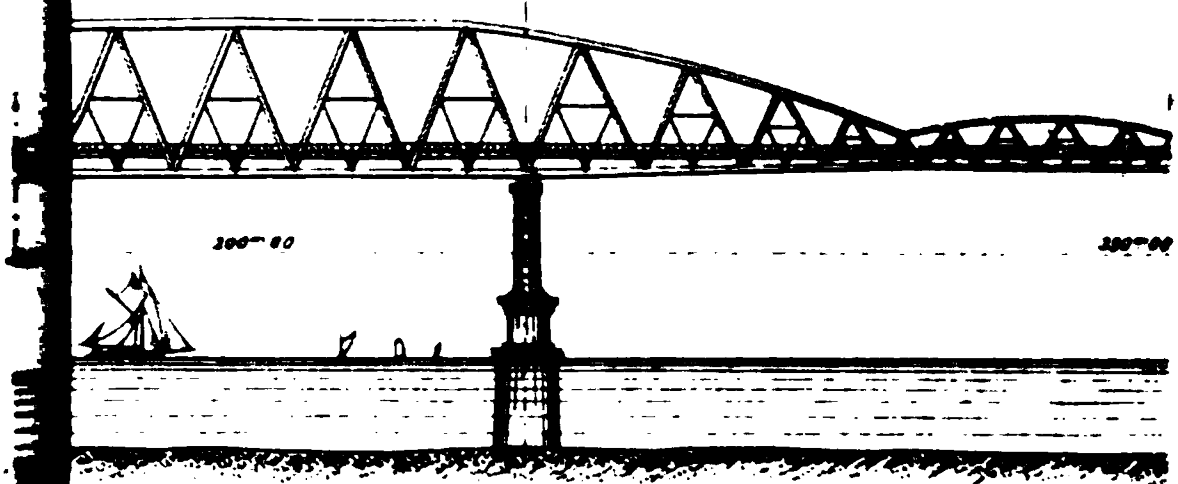
The first works visited were those of the Saint-Marcel at Aulnoye, which are devoted to the manufacture of wrought iron. The party afterwards visited the blast-furnaces, steelworks, and rolling-mills of Providence, where sheets, plates, and merchant iron are produced. The other works visited were those of Maubeuge blast-furnaces, rolling-mills, and foundries; and the works of Tilleuil, belonging to the Vezin-Aulnoye Company at Maubeuge, where merchant iron is produced.

The *Comité des Forges du Nord*, of which M. Martelet is the chairman, entertained the members at luncheon at Tilleuil, when M. Jambille proposed the toast of the Iron and Steel Institute and its President; and among the other toasts given were the forgemasters of the North of France, and the French iron industry

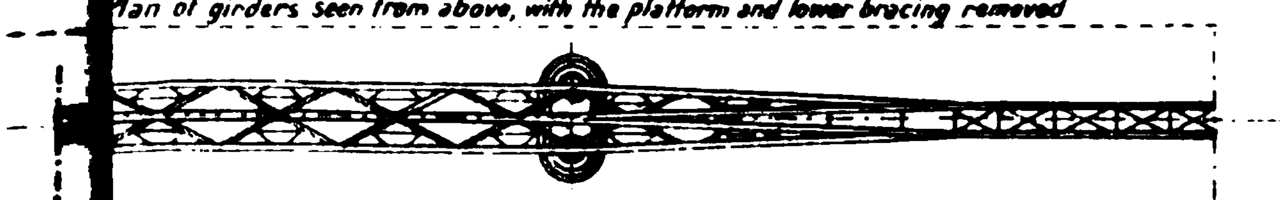
It was proposed that a fifth excursion should be made to the steelworks of Isbergues, in the Pas-de-Calais, but the number of members who gave in their names was so limited that the idea was abandoned.

PLATE I.

CO.'S



Plan of girders seen from above, with the platform and lower bracing removed



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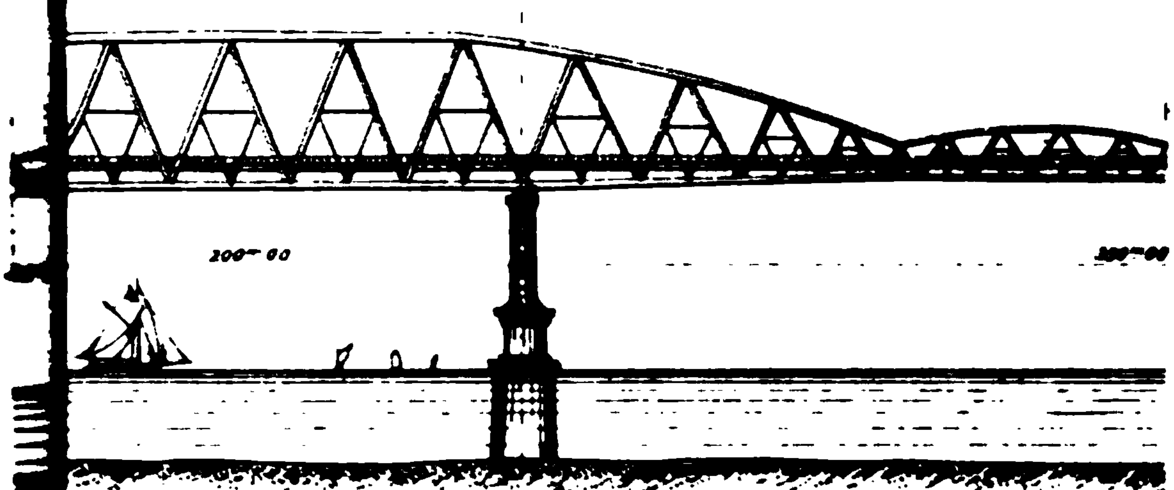
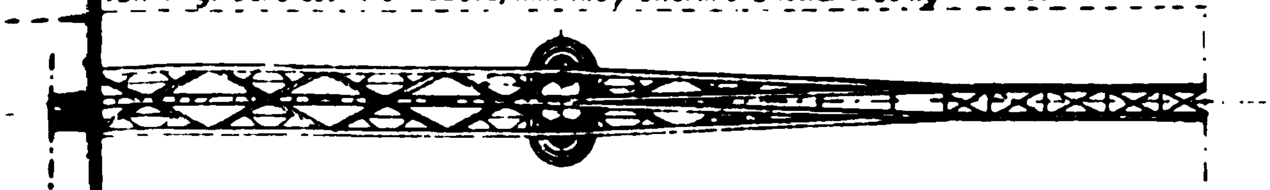
Ballantyne, Hanson & C° Edinburgh & London.

PLATE I.

CO.'S



Plan of girders seen from above, with the platform and lower bracing removed



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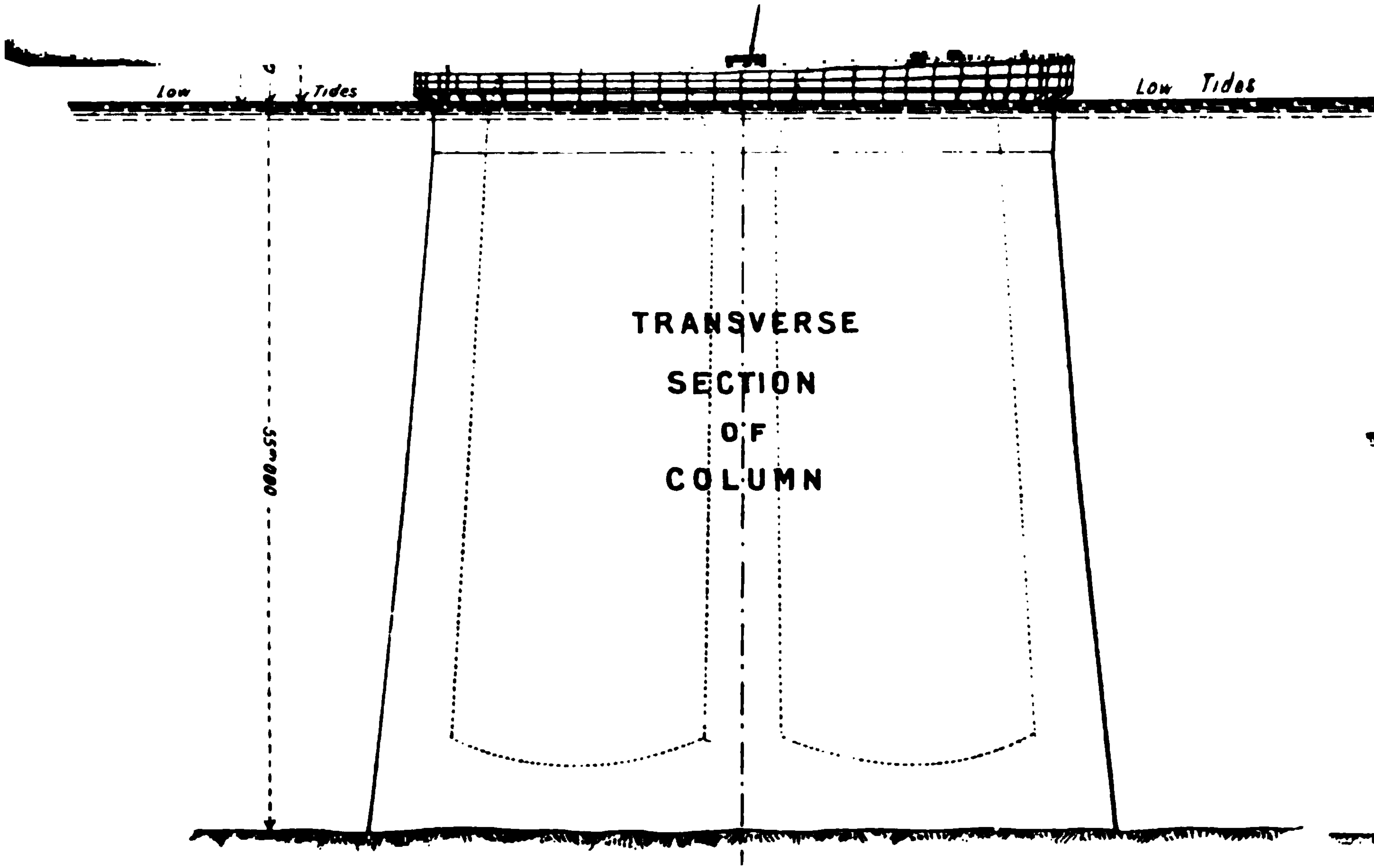
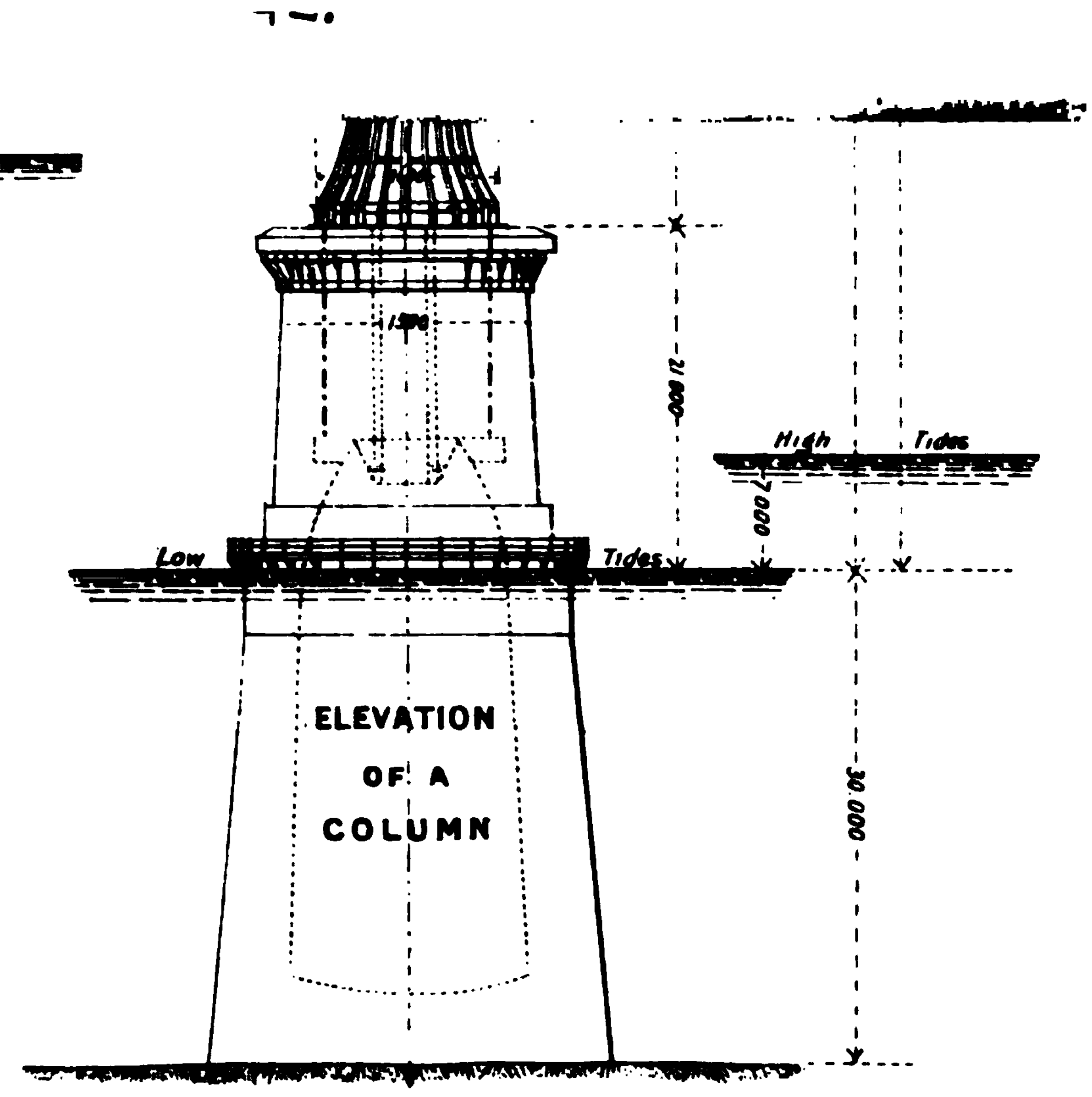


Superstructure—Preliminary Designs.
Spans of 300m. and 500m.

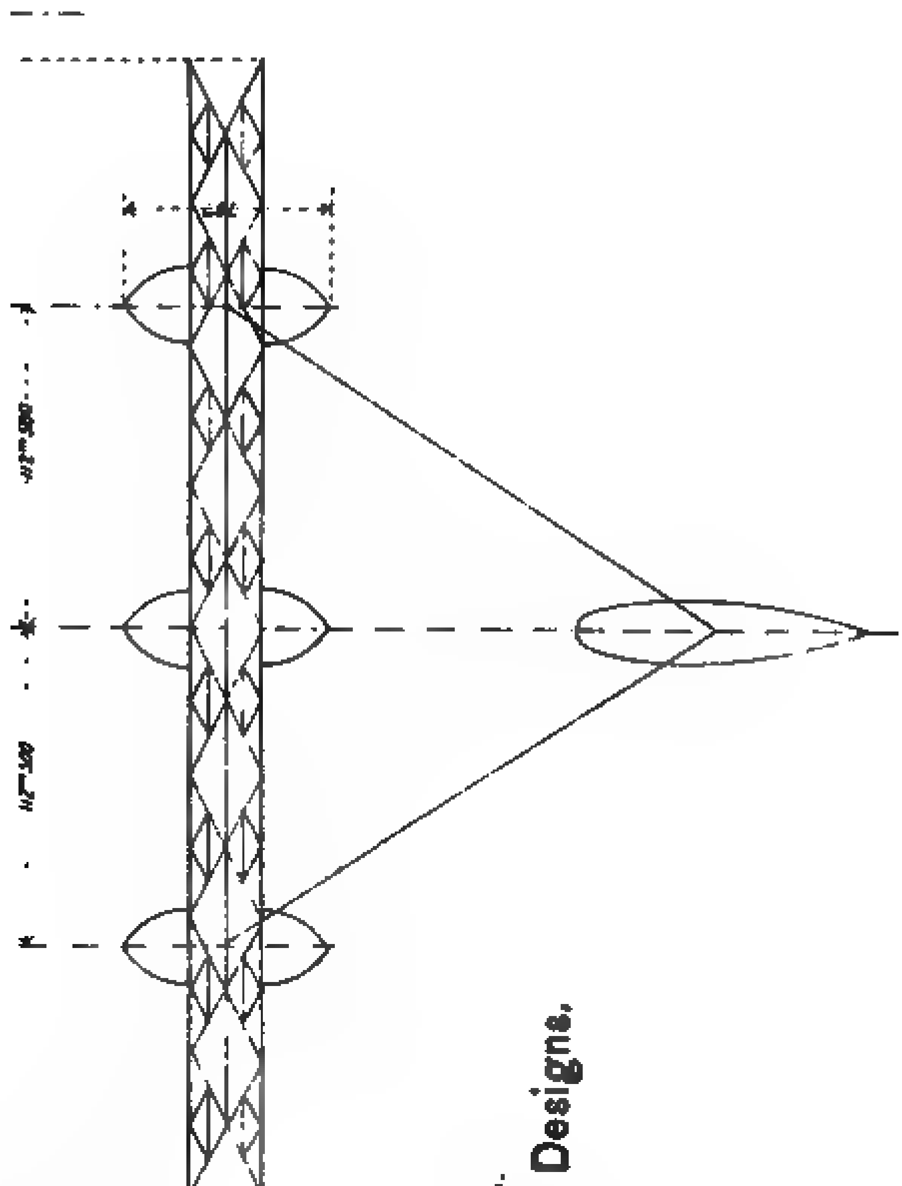


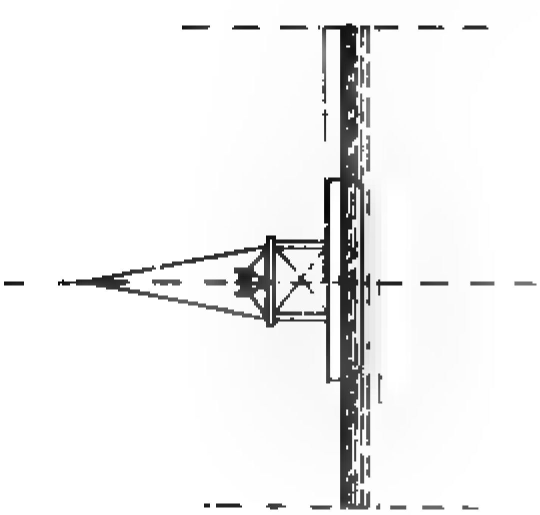
Superstructure—Preliminary Designs.
Spans of 200m. and 350m.

Ballantyne, Hanson & Co. Edinburgh & London.

PLATE III.

TO ILLUSTRATE MESSRS. SCHNEIDER & CO.'S PAPER ON THE CHANNEL BRIDGE.





TRANSPORT OF THE SPANS.

Superstructure—Preliminary Designs.

Ballantyne, Hanson & Co. Edinburgh & London.

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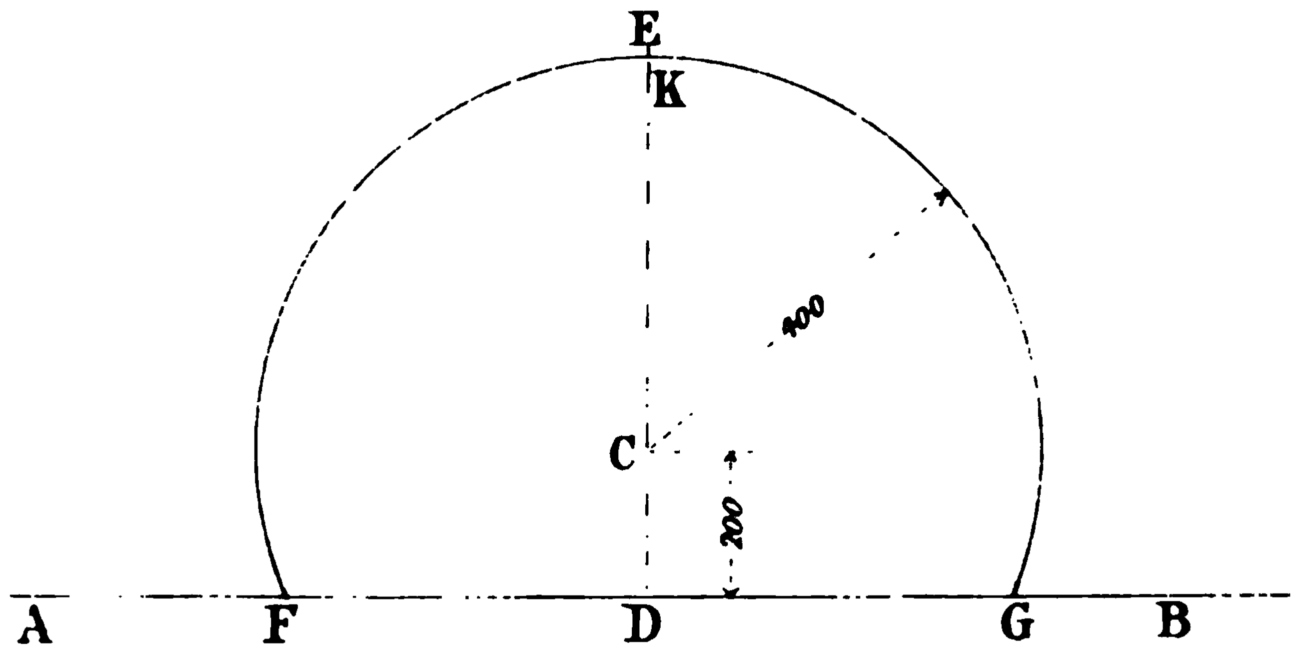
TO ILLUSTRATE MR. F. L. GARRISON'S PAPER ON "THE ROBERT BESSEMER STEEL PROCESS."

Fig. 6.



SECTIONAL

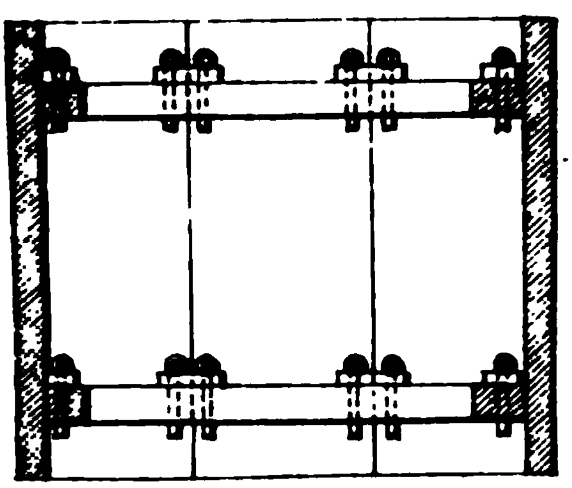


Fig. 7.

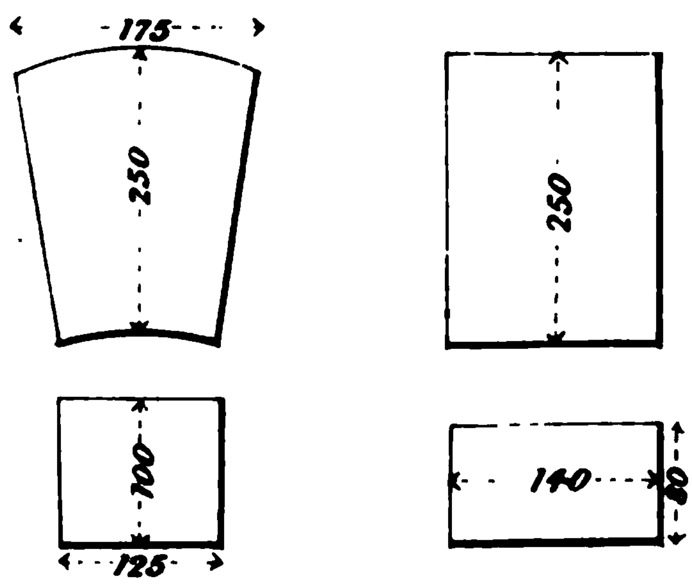
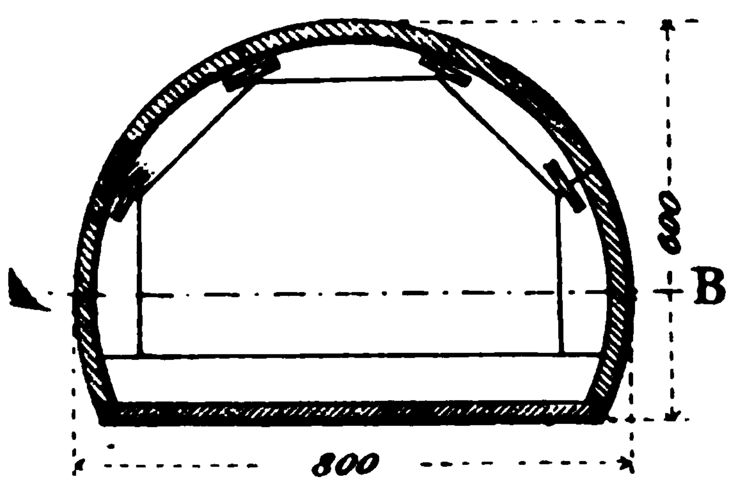


Fig. 8.



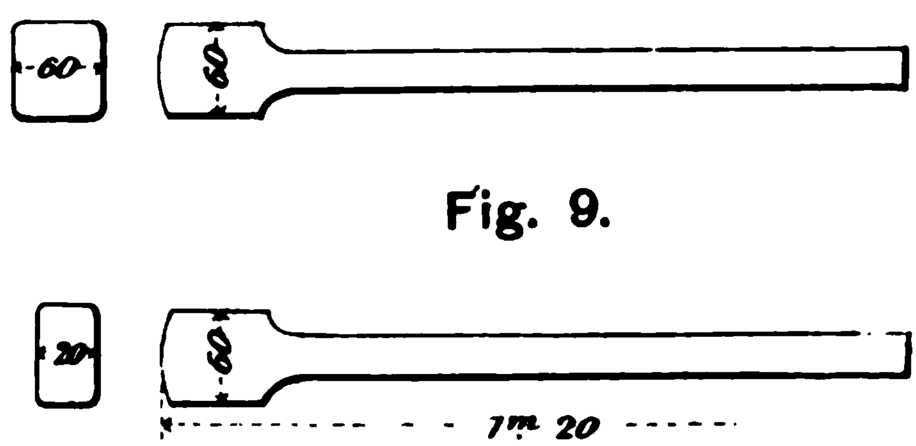


Fig. 9.

Ballantyne, Hanson & Co. Edinburgh & London.

PLATE XI.

TO ILLUSTRATE THE BASIC BESSEMER PROCESS AT LONGWY STEEL WORKS.

CONTENTS %

Time in minutes

Diagram showing the course of dephosphoration in the basic Converters.

Phosphorus - - - - - - - -

Manganese — — — —

Carbon ....

Silicon — — — — — —

Sulphur ————————

Operation No. 339 on the 17th August 1889.

Addition of 0·5 % ferromanganèse à 63 %; Lime 17·5 %.

FINAL STEEL.

Annealed—Resist. 38^{k}.3 A. 29

Hardened— " 46^{k}.7 All. 20

Ballantyne, Hanson & Co. Edinburgh & London.

TO ILLUSTRATE MR. F. L. GARRISON'S PAPER ON "THE ROBERT BESSEMER STEEL PROCESS."

Fig. 6.

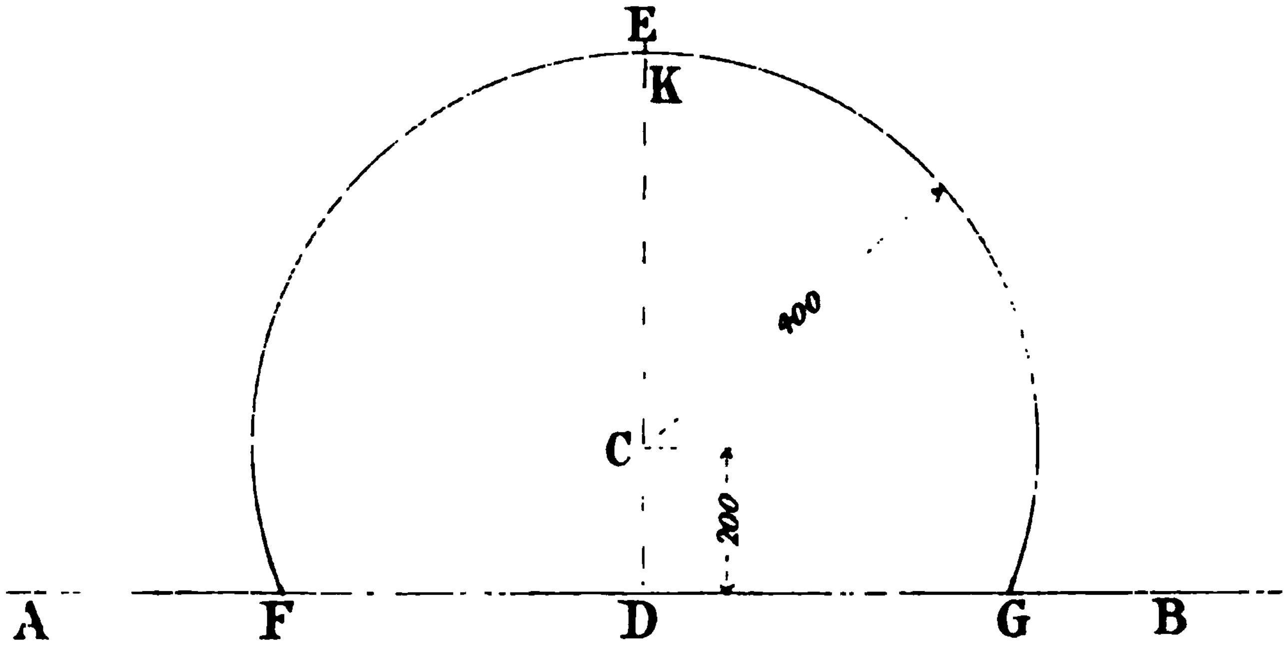
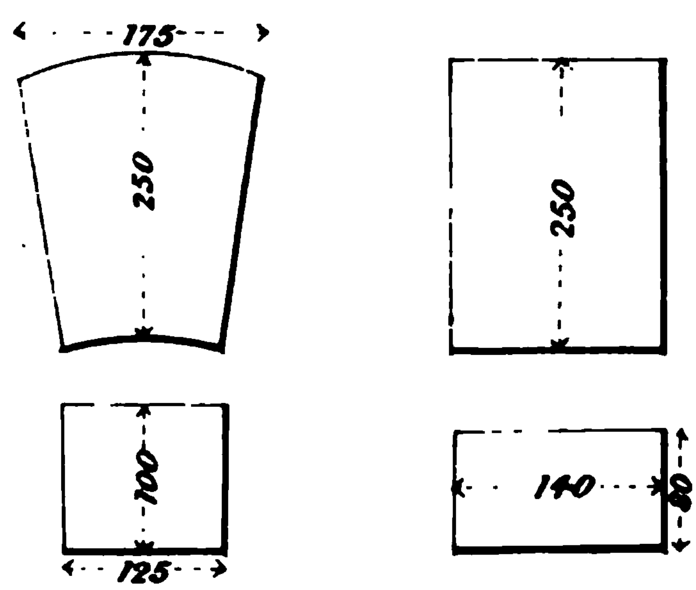


Fig. 7.



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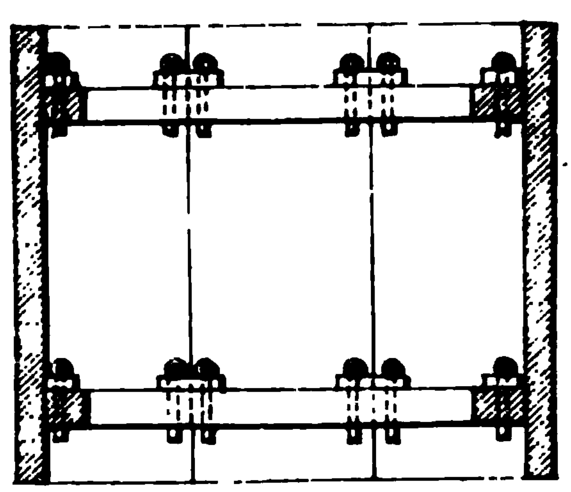
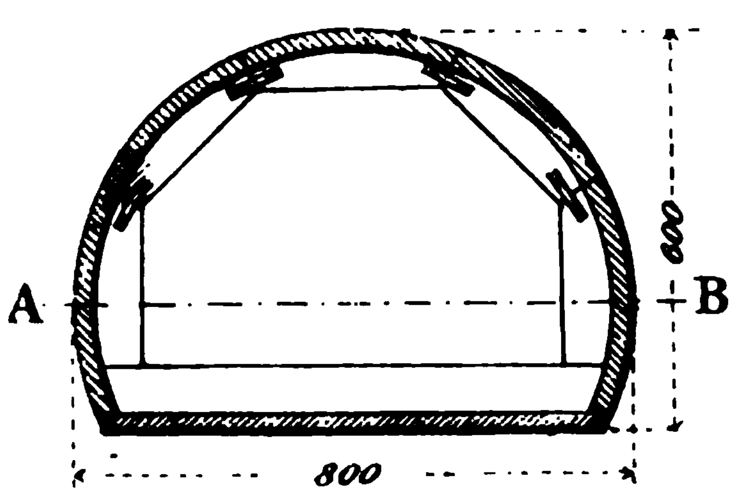


Fig. 8.



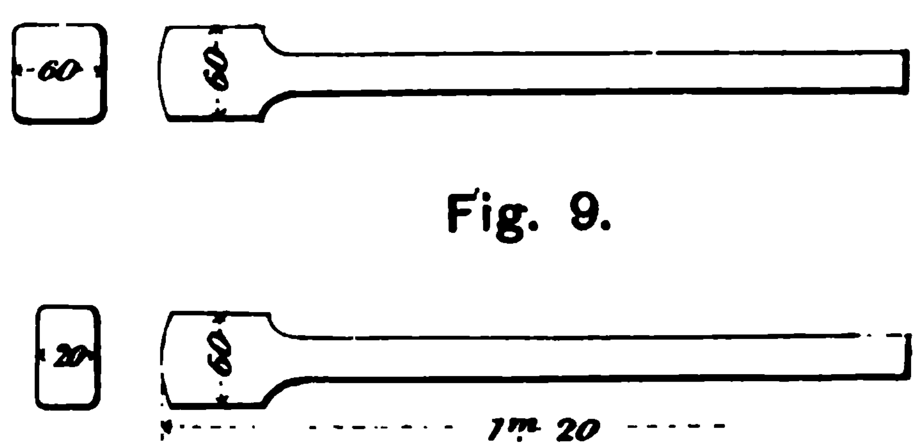


Fig. 9.

Ballantyne, Hanson & Co. Edinburgh & London.

NOTES

ON THE PROGRESS OF THE

HOME AND FOREIGN IRON AND STEEL INDUSTRIES.

II.—1889.

CONTENTS.

ABSTRACTORS.

EDWIN J. BALL, Ph.D.

BENNETT H. BROUGH, Assoc. R.S.M.

IRON ORES.

CONTENTS.

I.—*OCCURRENCE AND COMPOSITION.*

Geological History of Iron Ores.—A valuable contribution to the geological history of iron ores has recently been made by Mr. W. H. Hudleston.* An iron ore is defined as a mixture of oxides or salts of iron with earthy or carbonaceous impurities, and containing from 72 per cent. of iron downwards. Excluding sulphur compounds, there are only four minerals of importance, namely, magnetite, hæmatite, limonite, and chalybite. Iron is probably the prevailing element in the solar system; meteorites show that there is abundance of iron in Kosmos, so that it probably exists to a large extent in the centre of the earth. The most abundant iron silicates are mica, hornblende, and augite, and next come olivine and hypersthene. These minerals are variously acted on by carbonic acid. By studying the relation of iron to oxygen, and, secondly, the action of carbon products upon these elements, the conclusion is arrived at that a large proportion of iron ores is engendered by vegetable decomposition, such processes acting as accumulators of the ore itself. The reactions are illustrated in the formation of bog ore. Iron bicarbonate dissolved in the water is decomposed by oxygen, the oxide becomes hydrated and sinks. Then again, decomposing organic matter abstracts the oxygen, and so the solution and precipitation is kept up indefinitely till some cause leads

* *Proceedings of the Geologists' Association*, vol. xi. pp. 104–144.

annually, whilst the output in France itself is steadily diminishing, as will be seen from the following table :—

Year.	Output.	Value.	Workpeople employed.
	Tons.	Francs.	
1836	2,275,000	4,988,000	13,042
1846	3,008,000	7,768,000	12,870
1856	4,608,000	16,455,000	20,584
1866	3,790,000	13,626,000	12,263
1876	2,393,000	13,371,000	9,296
1886	1,999,000	6,915,000	5,411

The ores from the Department of Meurthe-et-Moselle supply a large part of the blast furnaces of North-East France. The Micheville mines, 10½ miles from Longwy, afford a good example of the mode of occurrence of the ore in this Department. The ore found is an oolitic ironstone, and three different kinds are won :—

(1.) An upper calcareous deposit, 8 feet 4 inches in thickness, poor in iron, the composition being as follows :—

Silica.	Alumina.	Lime.	Iron.	Phosphoric Anhydride.
13·40	6·70	18·80	27·02	1·16

(2.) A second bed, 6 feet 6 inches thick, of which the following is an average analysis :—

Silica.	Alumina.	Lime.	Iron.	Phosphoric Anhydride.
15·85	6·87	4·77	40·80	1·45

(3.) A third and still lower bed, 5 feet thick, having the following composition :—

Silica.	Alumina.	Lime.	Iron.	Phosphoric Anhydride.
13·23	7·07	7·24	39·80	1·46

The second or intermediary deposit is the one chiefly worked, as this ore is found to give the best results in the blast furnace. Over 100,000 tons a year are raised from this bed.

At Dielette, on the coast of Normandy, six beds of iron ore have been found. These vary in thickness from 10 feet to 46 feet. Altogether the net quantity of ore at present available in these beds is over 70,000,000 tons. The following is an analysis of the ore :—

Fe_2O_3.	FeO.	MnO.	MgO.	CaO.	Al_2O_3.	SiO_2.	P_2O_5.	Loss.
66·24	12·62	0·89	1·79	2·45	3·94	10·22	1·00	0·66

The ore occurs in a number of parallel beds of iron ore and quartzite adjoining granite. They are worked by a vertical shaft from which a

Chrome Iron Ore from Orsova.—The chrome iron ore found in the serpentine, occurring near Orsova, on the Danube, has, according to A. Gouvy,* the following composition :—

Cr_2O_3.	F_2O.	Al_2O_3.	CaO.	MgO.	SiO_2.	Total.
38·95	16·13	17·50	2·20	17·20	8·00	99·98

In another sample the percentage of alumina reached 27·75.

Messrs. Gauss Brothers, of Vienna, are erecting near Orsova a works for the manufacture of ferro-chrome from the chrome iron ore found in that neighbourhood. This ore has the following percentage composition :—

Cr_2O_3.	Fe_2O_3.	Al_2O_3.	MgO.	CaO.	SiO_2.
53·00	35·32	8·20	2·00	trace	2·40

A number of other analyses are also published by R. Busek.†

Iron Ore from Mont Ara.—The following are analyses of Spanish iron ores exhibited at the Paris Exhibition by the Bidassoa Railway and Mining Company, Irun :—

	Brown Hæmatite.	Brown Hæmatite.	Spathic Ore.
	Per cent.	Per cent.	Per cent.
Ferric oxide	78·72	81·81	5·86
Ferrous oxide	...	...	48·86
Manganese oxide	2·51	2·64	5·61
Alumina	1·19	0·20	0·70
Lime	0·61	0·63	0·21
Magnesia	...	...	1·08
Phosphorus	...	...	...
Sulphur	0·10	0·12	0·10
Silica	5·87	3·25	1·84
Carbonic anhydride	...	...	34·95
Moisture and organic matter	11·00	11·25	1·50
Metallic iron	55·09	57·25	41·55
Metallic manganese	1·94	2·04	4·35
Moisture	3·01	8·37	0·11

A partial analysis of roasted spathic ore showed 56 per cent. of iron and 6 per cent. of manganese.

Magnetite in North Sweden and in the Ural.—H. von Schwarze ‡ points out in what respects the magnetite mountains of North Sweden differ from those of the Siberian Ural, and in what respects they are similar.

* *Stahl und Eisen*, vol. ix. p. 398.
† *Ibid.*, vol. ix. p. 729.
‡ *Zeitschrift des Vereines deutscher Ingenieure*, vol. xxxiii. pp. 783–785.

however, is of frequent occurrence in the coal series of Vancouver and Queen Charlotte Islands, as well as in the tertiary rocks of the interior. The only iron ore deposits which have yet been worked are those of the south-west side of Texada Island, the largest exposures of ore occurring about 3 miles north-west of Gillies Bay. Here the ore mass is from 20 to 25 feet in thickness. It constitutes an irregular contact deposit between limestone and granite. The ore is magnetite of excellent quality, containing nearly 70 per cent. of iron. At the principal deposit of the ore a wharf has been built. The ore is brought down from the quarry to the wharf by an incline, the height of the quarry above sea-level being 250 feet, and the length of the incline ¼ mile. The shipments in 1885 amounted to 190 tons; in 1888 the quantity shipped was 7300 tons, valued at £3680. Magnetite is also found at the Queen Charlotte Islands, the ore being, as a rule, very pure, an exceptionally good specimen yielding on assay 69·88 per cent. of iron. Very pure ore containing 71·57 per cent. of iron was also found at an island in the Walker Group, Queen Charlotte Sound. Other deposits exist at Sooke Harbour, Vancouver's Island, and at a number of other places.

Iron Ore in Canada.—Mr. A. Evans, junr.,* states that only one furnace is in blast in Nova Scotia, and none in New Brunswick. The furnace is at the Arcadia Mines, and practically only supplies iron for its own works. Ore seems to be very scarce, and of poor quality, as the following analyses show:—

	Insoluble.	P_2O_5.	Fe_2O_3.	FeO.	Al_2O_3.	Mn.	CaO.	MgO.	Fe (average).
I.	5·48	...	51·18	2·39	2·81	1·36	2·80	4·40	31·00
II.	16·00	0·57	...	...	0·86	...	...	0·46	40·00

Sample No. I. was calcareous limonite from the Toten Mine, Londonderry, and No. II. was from the West Mine.

The Flax-Seed Ore of Wisconsin.—This remarkable iron ore deposit has been recently described by Mr. J. Birkinbine.† There is, the author observes, probably no place in the United States where a large quantity of iron ore can be mined more cheaply than from the Iron Ridge deposit of Wisconsin.

* *Bulletin of the American Iron and Steel Association*, vol. xxiii. p. 268; *American Manufacturer*, vol. xlv., No. 14.

† *Journal of the United States Association of Charcoal Iron Workers*, vol. viii. pp. 241-250.

at a greater elevation. The transport would thus be more difficult. An analysis of ore from this claim gave the following results:—

SiO_2.	Fe.	CaO.	S.	P.
2·80	69·32	0·30	0·084	0·039

An immense deposit of titaniferous iron ore exists in the Cebolla district. The lowest analysis shows 9·38, the highest 36 per cent. of titanium. Iron ore is also found in Elkhorn Mountain, and solid manganese ore, containing 52·2 per cent. of manganese in a vein 2 feet thick, is found in Powder-horn Hill. A poor limonite occurs close by, in what appears to be a bedded deposit.

Thirteen miles from the railroad and twenty-seven from Gunnison City, there is a large deposit of manganiferous iron ore of the following composition:—

	SiO_2.	MnO.	Fe_2O_3.	CaO.	MgO.	CO_2.	Mn.	Fe.
Unroasted . .	0·82	13·92	39·01	19·55	6·03	21·05	...	...
Roasted . . .	1·04	17·62	49·38	24·74	7·63	...	13·65	34·57

A pure limestone is found in numerous localities, with the following composition:—

Siliceous matter.	Fe_2O_3 and Al_2O_3.	$CaCO_3$.	MgO.
1·44	0·13	98·17	traces

Coal of suitable quality is also found at Elkhorn. An estimate of the cost of smelting is given as about £2, 10s. per ton.

Bog Iron Ore in Colorado.—An analysis of bog iron ore from Crested Butte, by Prof. R. Chauvenet,* gave the following results:—

Water and Organic Matter.	SiO_2.	Fe_2O_3.	Al_2O_3.	CaO.	MgO.	P.	Fe.
23·97	2·50	72·47	0·28	0·22	0·12	0·145	50·73

Iron and Manganese Ore in Georgia.—In connection with the sale of iron and manganese mines situated in the vicinity of Cartersville, Georgia,† the following analyses have been made:—

Grey Specular Ores.

	No. 1.	No. 2.
Metallic iron	66·283	61·496
Phosphorus	0·024	0·012

Brown Ores.

	Crow Bank.	Hurricane Mountain.	Wheeler Bank.
Metallic iron	53·371	55·697	47·470
Phosphorus	1·673	0·609	0·958

* *Report of the State School of Mines, Golden, Colorado*, p. 29.
† *The Age of Steel*, vol. lxvi., No. 13, p. 17.

Recent Researches on Meteorites.—E. Cohen * has analysed portions of the various constituents of the meteoric iron from S. Juliãs de Moreira, Minho, Portugal. After subtraction of the schreibersite, the nickel iron gave :—

Iron.	Nickel.	Cobalt.	Copper.
92·92	5·98	1·01	0·09

A similar composition is exhibited by several other hexahedral irons. The crust of the meteorite was found to consist of a mixture of nickel, iron, and schreibersite, with products of their decomposition. The iron sulphide was found to consist of 60·14 per cent. of troilite, and 37·58 per cent. of ferric oxide. The schreibersite gave, on analysis, results corresponding with the formula : $Fe_5(NiCo)P_2$. The analysis showed 1·31 per cent. of cobalt, an unusually large proportion.

S. Meunier † gives the results of the examination of a specimen forming part of a meteoric mass found in 1880 at Eagle Station, Kentucky. Ornaments made from portions of this meteorite have been found in a prehistoric burial mound in the vicinity. The meteorite has the structure of the ordinary syssiderites, and consists of a metallic mass, with numerous vacuoles filled with stony matter. The metallic mass has a concretionary structure, and contains the alloys tœnite, Fe_6Ni, and kamacite, $Fe_{14}Ni$. It does not resemble the Atacama meteoric iron, since it contains augite associated with olivine. It has, in fact, the characteristics of the type of syssiderites distinguished in 1870 by the author by the term brahinite. The only specimen of this kind hitherto known is the meteoric mass found in 1822 at Brahin in Russia.

Daubrée ‡ describes a meteorite, 4½ lbs. in weight, that was found in the earth at Hamel-el-Requel, Algeria. It belongs to the holosiderite class, and externally resembles the Rio-Juncal meteorite. It is believed to have fallen in quaternery time.

J. E. Whitfield § has analysed a meteorite from the State of Durango, Mexico, and finds it to have the following percentage composition :—

Fe.	Ni.	Co.	P.	S.	C.
91·48	7·92	0·22	0·21	0·21	0·06

Troilite was observable in the meteorite, which was partially decomposed

* *Jahrbuch für Mineralogie*, 1889, No. 1, pp. 215–223.

† *Comptes Rendus de l'Académie des Sciences*, vol. cxviii. pp. 762–773.

‡ *Ibid.*, vol. cviii. pp. 930–931.

§ *American Journal of Science*, vol. xxxviii. p. 439.

to recover the ore reserves and pillars by building brick arches, but without success. The method now adopted is to remove the whole of the country rock on the hanging wall in some parts as far down as the 300-foot level. Up to April this year, about 234,570 cubic yards had been removed, and of this 7211 cubic yards consisted of ore. At the narrow ends of the ore body, derricks are placed, and wire cables are stretched across the intervening space. Two of these are horizontal, and two are fixed to points about 100 feet below the surface. Sliding trolleys are carried by the ropes, and their positions are controlled by the winding-engines. The winding-ropes pass over pulleys on the trolleys. In order to save time, the bodies of the trucks are taken off their wheels and lowered into the pit for loading. Subsidiary cables are used for handling the stuff in the mine. By this method 1000 tons of rock are handled every ten hours.

The Transport of Iron Ore in Spain.—In a series of articles, F. Gisbert * describes the methods in use for the transport of minerals at the Sierra de Cartagena. Large quantities of iron ore are raised in the district and are exported by sea, the ports being Carthagena and Portman. From the mines to these ports the means of transport consists partly of aerial tramways, inclines and steam tramways, but from the smaller mines, or in rough country, the ore is chiefly sent in panniers on donkeys. The author describes in detail the aerial tramways at the Crisoleja and La Lucera mines. The first of these mines is the most important. The ore is limonite, containing about 50 per cent. of iron. It occurs in the form of a seam averaging about 26 feet in thickness. The pillar-and-stall mode of mining is adopted. The various parts of the wire ropeway connecting the mine with Port Portman are described by the aid of a number of diagrams. The Otto system is employed, the length of the rope being nearly 1¼ mile, the difference in elevation of the starting-point at the mine and the terminus at the port being 633 feet. The bearing rope is 1·18 inch in diameter, and the hauling rope 0·47 inch. The waggons are placed at intervals of 131 feet, each one holding from 550 to 660 lbs. The cost of transport of the ton of ore by this cable from the mine to the port was slightly less than twopence.

At the Lucera Mine the same deposit of ore is worked as at the Crisoleja Mine. The ore is taken to Port Portman by an Otto aerial tramway 1·40 mile in length, with a difference in level between the

* *Revista Minera*, vol. xl. pp. 233–235, 243–245, 249–252.

REFRACTORY MATERIALS.

Fireclay Industry of Grossalmerode.—According to Wiggert,* the fireclay deposits of Grossalmerode, Hesse, are of Tertiary age. The clay has the following percentage composition (I.):—

	I.	II.	III.	IV.
Al_2O_3	34·52	31·63	33·68	19
SiO_2 chem. combined	43·38	34·44	49·90	70
SiO_2 mech. mixed	6·53	21·03		
MgO	0·37	0·25	0·44	...
CaO	0·76	0·15	0·48	...
Fe_2O_3	1·66	0·70	1·90	3
K_2O	1·51	0·38	1·81	...
S	0·26	0·08	0·03	...
Loss on ignition	11·04	11·40	11·63	7

For comparison, analyses are given of clay from Löthain near Meissen (II.), from Klingenberg on the Main (III.), and from Stourbridge (IV.).

The clay is worked in an economical manner by means of small shafts and adit levels. The production of fire-clay in 1885 amounted to 32,700 tons, and the industry afforded employment to 284 workmen.

Calcining Magnesite.—According to J. von Ehrenwerth,† magnesite must be exposed to an intense heat before it is used in the basic steel furnace, in order to drive off the carbonic anhydride and to prevent any further shrinkage. The contraction may amount to 50 per cent. When the material is burned in the ordinary lime kiln, the ash of the fuel is a disadvantage, and the operation of drawing is attended with great difficulty on account of the intense heat. The open-hearth furnace having being found well suited for magnesite in Styria, the author has designed a combination of a reverberatory furnace with a gas-fired kiln, drawings of which are given in the original memoir. The firing is effected by producer gas. The cost of a furnace of this description capable of producing 5 tons of dead-burnt magnesite daily amounts to £416 to £583, inclusive of gas-producer and stack.

* *Zeitschrift für das Berg-, Hütten- und Salinenwesen*, vol. xxxv. p. 336.

† *Oesterreichische Zeitschrift für Berg- und Hüttenwesen*, vol. xxxvii. p. 102.

Fireclay from Moravia.—The clays and clay-slates of the Müglitz-Briesen district in Moravia are extremely refractory. Hecht * gives the following analyses of material from this district: 1. Clay from the Anton Mine; 2. Clay from the Ferdinand Mine; 3 and 4. Clay slates from the Anton Mine near Briesen; 5. Carboniferous sandstone from the Werner adit level:—

	1.	2.	3.	4.	5.
Silica	45·61	44·87	43·48	46·13	73·42
Titanic anhydride	...	...	...	0·16	...
Alumina	39·31	39·76	39·43	36·24	19·60
Ferric oxide	1·13	1·14	1·61	1·26	0·55
Lime	0·37	0·76	0·22	0·60	...
Magnesia	trace	trace	trace	0·12	trace
Potash	0·66	0·67	0·34	0·85	0·21
Loss on ignition	13·25	12·95	15·26	14·68	6·66
Totals	100·33	100·15	100·34	100·04	100·44

The sandstone (No. 5) is a good fire-resisting material. When submitted to a fire-resistance test in a Deville furnace it was found to have a melting-point lying between Nos. 33 and 34 of the Seger scale.

Both the slates (Nos. 3 and 4) are extremely hard, and of fine grain. They withstand elevated temperatures extremely well, being almost as good fire-resisting materials as the best Zettlitz china clay—they are, in fact, almost infusible.

French Fireclays.—The following are analyses (A) of the Breteuil kaolin, and (B) of a brick made from the fireclay occurring at Forges les Eaux, exhibited at the Paris Exhibition:—

	H_2O.	SiO_2.	Al_2O_3.	Fe_2O_3.	CaO.	MgO.	K_2O.	Na_2O.	Totals.
A.	9·30	41·38	47·80	trace	0·84	...	0·20	0·56	100·08
B.	0·60	76·99	19·67	0·84	1·50	0·40	...	...	100·00

The firebrick is stated to be of exceptionally good quality.

* *Centralblatt für Glasindustrie und Keramik* (Vienna), vol. iv. p. 212.

	Coal.					
Ash	3·01	1·92	1·27	3·20	2·41	1·90
Fixed carbon	65·07	63·03	65·12	55·76	60·75	58·61
Volatile matter	30·74	33·83	32·24	41·04	34·12	37·73
Sulphur	1·20	1·20	0·56	1·01	0·48	1·95
Water	0·93	1·17	...	...	2·24	...

	Coal.		Coke.			
Ash	7·36	6·00	4·78	10·49	6·20	10·54
Fixed carbon	50·69	68·34	92·30	85·77	92·32	87·30
Volatile matter	41·12	22·15	1·60	3·04	0·40	0·80
Sulphur	0·42	1·85	1·12	0·54	0·82	1·19
Water	0·83	1·66	0·20	0·15	0·25	0·15

The mines which are at present in operation have a capacity of 6800 tons, other mines which are being opened will increase this total by 2900 tons daily. The average of coal owned by companies is 233,000 acres, the rest is still Government property.

In an article published in another journal,* it is stated that the Underwood seam, worked by the Cahaba Coal Mining Company, Alabama, is 6 feet thick, and lies in a basin about 2½ by 5 miles long, with a dip of 5 to 10 degrees. The following assay is given of the coke:—

	Coke.
Moisture	...
Volatile matter	4·508
Fixed carbon	87·607
Sulphur	0·745
Ash	7·140
	100·000

North-Western Colorado Coal Region.—A coal region covers an area of about 150 miles square on the northern half of the Pacific slopes of Colorado. Mr. G. C. Hewett † describes the formations above the Carboniferous as being largely developed, while all below are but meagrely shown. The whole geological section is torn and distorted in every period, so that the Carboniferous strata are much crushed and twisted, and accordingly the coal is not likely to be of much value. The productive Cretaceous coal measures are 700 to 1200 feet thick, and contain two or three beds of coal. Farther above, in the Tertiary strata, are some oil shales.

The coal measures lie in two fields—one lies between the rivers Gunnison and Yampa, the other is an extension of the Green River

* *American Manufacturer*, vol. xlv., No. 6.

† *Transactions of the American Institute of Mining Engineers*, vol. xvii. pp. 375-380.

field in Wyoming. When unchanged by flexure, the seams carry lignite, with 5 to 20 per cent. of water. In some parts the changes from anthracite to coking and non-coking coals are exceedingly rapid.

The author then proceeds to describe the general trend of the outcrop, and to indicate the position where good coal is found in more or less accessible positions. The floor and roof of the seams are generally composed of clay slate that slacks and crumbles on exposure. These facts, together with the dip of the seams, render mining a difficult operation.

Coal in Gunnison County.—After dealing with the iron ores of Gunnison County, Colorado, Professor R. Chauvenet * gives the following assays of coals and cokes from that locality :—

	Coal	Coke.	Coal.		
Water	1·18	...	1·58	0·90	9·29
Volatile matter	28·39	0·42	5·66	33·43	30·93
Fixed carbon	67·06	90·71	89·76	61·25	55·72
Ash	3·37	8·87	3·00	4·42	3·48
Sulphur	...	0·37	...	...	0·58

Coal in Kentucky.—The coal in the Jellico district † appears to be an extension of that in the Elkhorn coalfield. It lies on a strong fireclay floor, and the roof is a heavy layer of sandstone, without apparent intervention of shale. At the bottom is 22 inches of coal, then 7 inches of clay-parting, and then 28 inches of coal. Two assays of the coke are given ; the first was coked for 48 hours.

Moisture	0·20	1·50
Volatile combustible matter	1·35	...
Carbon in the coke	95·20	93·30
Sulphur	1·23	0·382
Ash	3·25	5·20
Specific gravity	1·50	...
Percentage of cells by volume	61·0	...
Weight lbs. per cubic foot	55·87	...

Bernice Anthracite Basin.—This basin is the westernmost and largest of the deposits in Sullivan and Wyoming Counties, Pennsylvania. The basin, which is described by Mr. C. R. Claghorn,‡ is

* *Report of the State School of Mines, Golden, Colorado*, pp. 24–25.
† *American Manufacturer*, vol. xlv. No. 11.
‡ *Transactions of the American Institute of Mining Engineers*, vol. xvii. pp. 606–616.

III.—*COKE.*

A New Coke Oven.—Messrs. Bernard and Seibel exhibited at the Paris Exhibition drawings of a modified form of the Seibel horizontal oven. The oven is intended more particularly for the treatment of badly coking coals. In this oven the coal begins to coke at the upper part of the coking chamber, the coking gradually proceeding from the top downwards. The temperature should be as high as possible. The oven resembles the Belgian type. The gases escape through openings in the roof, pass upwards to a combustion chamber, and then descend through a series of openings to two channels below the oven, pass thence below the bed of the adjoining oven, and finally escape to the stack through a channel common to the whole of the battery. Ovens of this type were erected at the Karwin collieries in Austria in 1887. Some of the ovens erected are 29 feet 6 inches in length, 5 feet 3 inches high, and 2 feet wide. Others have been built still higher, about 6 feet 6¾ inches.

Coke Ovens at the Isbergues Steelworks, France.—At these works there are 100 coke ovens of the Evence Coppée or Siebel-Bernard type.* These ovens are 29 feet 6 inches in length, 6 feet 7 inches in height, and 2 feet in width. The coal coked is bituminous coal from the Pas-de-Calais. The charge is about 7 tons, and the yield from 5·2 to 5·3 tons of coke, containing 12 per cent. of ash, the volatile products of the coal being about 23 per cent.

The Bauer-Ruederer Coke Oven.—Messrs. Bauer and Ruederer of Munich publish † a sketch plan and section of a 24-chambered coke oven battery. This battery is circular, the chambers being arranged radially around a central stack. The chambers are vertical ones, the charging being effected at the top in the usual manner. Each chamber holds 2 tons of coal, and the duration of the coking is from eighteen to twenty-four hours. The formation of the chambers admits of a rapid withdrawal of the coke, the time required varying from six to ten minutes. The coke falls on to a rotating band, on which it is cooled, separated from smalls, and automatically discharged into waggons. The combustion spaces are easily repaired. The various coking chambers are independent of one another, and are filled and discharged at

* *L'Echo des Mines*, vol. xiv. No. 41, p. 4.

† *Stahl und Eisen*, vol. ix. p. 788.

adopted, the exhaust was situated behind the coolers and the washers, now, on the other hand, it is placed between them. Practice has shown that only from 11 to 14 per cent. of the total nitrogen present in the coal is collected in the form of ammonia. Various methods have therefore been proposed for the purpose of increasing this percentage. Past experience has shown that with increasing temperature the percentage of ammonia also increases. The belief that ammonia dissociates at a temperature of 780° C., is therefore not confirmed by the results of practical work. Other experiments have shown that the percentage of ammonia increases perceptibly if hydrogen is passed through the coal undergoing dry distillation. Lime, too, has been found to increase the yield of ammonia, but it deteriorates greatly the quality of the coke produced, the strength being considerably diminished. This is probably due to the action of the water on the lime when the red-hot coke is cooled after drawing.

Efforts have also been made to increase the yield of tar by endeavouring to prevent the dissociation of tarry matter in the oven by the use of cooling arrangements. Good coke, however, can only be produced at a high temperature, so that the use of such cooling arrangements on the roof or sides of the oven tends to deteriorate the quality of the coke produced.

The ammonia collected in the condensers is converted into sulphate, the ammonia being first distilled off from the condenser water, lime being added to decompose any ammonium compounds present. A number of kinds of apparatus have been introduced for use in this process. The ammonia driven off is passed into sulphuric acid, which is diluted down to about 38° or 40° B. The sulphate is removed from time to time and fresh acid added.*

Some experiments † have been made with coke ovens arranged for the collection of the by-products at the Calumet Steelworks, United States. The ovens were erected by the National Coke and Fuel Company of Chicago, and the experiments showed that for every ton of coal coked there were obtained 15,000 cubic feet of fuel-gas, from 3 to 5 gallons of coal oil, and ammonia in quantity equivalent to about 3 lbs of the sulphate. In the beehive ovens, in which these experiments were made, the downward process was adopted, as in Jameson's ovens, the volatile matters being withdrawn through a hollow floor.

* *Stahl und Eisen*, vol. ix. pp. 482-485.
† *Iron Age*, vol. xliii. p. 692.

	s. d.	s. d.
Cost of coal	2 9·75	3 0·6
Coking	1 6·25	1 4·05
Royalty	0 6·05	0 6·05
Cost per ton	4 10·05	4 10·7

In the latter case labour costs 13·75 pence; supplies, 0·4 penny; and repairs, 1·9 penny per ton.

IV.—*LIQUID FUEL.*

Oil in New Zealand.—The New Zealand Government has recently issued a report dealing with the Taranaki district. The oil comes to the surface in many places near New Plymouth. Mr. Gordon * reports that oil exists over a large area, and that it is only a question of boring to the requisite depth. The oil-bearing districts could easily supply the fuel for the iron sand beaches of New Zealand.

Burmese Oil Fields.—Dr. F. Noetling † has reported on the oil fields of Burma. The Yenangyaung district is conveniently divided into the Twingoung and the Beme districts, situated in lat. 29° 21′ N., long. 94° 56′ E. The country forms an elevated plateau intersected by ravines. The strata belong to the Upper Tertiary formation, and consist of a soft sandstone impregnated with oil. At present the deepest borehole is only 400 feet, proving the oil-bearing strata to have a thickness of 200 feet, but the amount of oil increases largely with the depth. No high gas-pressure has as yet been found. The strata form an anticlinal, with a strike N. 40° E., and a maximum dip of 30° to the S.W. and N.E., so that most of the wells driven by the natives have been sunk on the top of the anticline.

In the Twingoung field there are 209 productive wells, producing 12,000 viss ‡ daily, but the wells are very shallow, the deepest being only 310 feet. The Burmese method of getting the oil is to sink a shaft about 4½ feet square, a matter of great difficulty, as the miners cannot breathe the explosive air, and only use most inefficient tools. A well, however, yields some 23 per cent. interest. There are 72 productive wells in the Beme district, with a daily production of 14,000 to 20,000 viss, and the deepest well is only 270 feet in depth.

* *Engineering*, vol. xlviii. p. 316.

† *Records of the Geological Survey of India*, vol. xxii. pp. 75–136.

‡ 1 viss = 3·65 lbs.

week was 46·7 gallons. It was found that the loss is somewhat greater than with coal gas, and some trouble was experienced from the clogging of the checquer-work by fine iron oxide. In a 5-ton open-hearth furnace 50 to 55 gallons were used per ton.

Mr. E. C. Potter * gives the results of using oil at the South Chicago Works in place of coal for raising steam. For operating fourteen tubular boilers, 16 feet long by 5 feet diameter, twenty-five men were required when coal was used and only six men when oil was substituted. With an ingot output of 6403 tons, 2731 barrels of oil were used as against 848 tons of coal. The saving in wages was £7, 18s. 4d. per day. Taking the oil at 2s. 6d. per barrel and coal at 8s. 11½d. per ton, the cost of oil and coal were respectively 8s. 0½d. and 8s. 11½d. per ton, giving a net saving of 11d. per ton.

For a similar battery of twenty-six boilers the rail output was 5208 tons, with a consumption of 5987 barrels of oil instead of 1805 tons of coal. In this case the costs were 8s. 3d. and 8s. 11½d. respectively. The efficiency of the boilers was somewhat increased and the necessary repairs diminished.

Mr. G. H. Billings † gives the results with the earlier form of the Archer apparatus applied to a puddling furnace. To heat the furnace 3518 lbs. were required, and 8437 lbs. more were burnt to give 13,340 lbs. of puddled blooms. At 2·44 pence per gallon the oil cost £2, 5s. 5½d. per ton of blooms, and the cost with coal at £1, 0s. 4d. per ton, using 1·5 ton of fuel per ton, was £1, 10s. 5½d. A run of six days used 6602 gallons for a production of 65,595 lbs. of blooms, and showed a saving in favour of coal of 18s. 9d. per ton.

For generating steam, 4156 lbs. of oil evaporated 27,600 lbs. of water per day. Assuming that one pound of coal evaporates nine pounds of water, with prices as above, the costs were £15, 19s. 11d. for oil, and £3, 6s. 6d. for coal, daily.

A test ‡ has recently been made of oil fuel in a puddling furnace. The oil is supplied through a perforated pipe on to a heap of fire-clay balls supported on the grate. The pipe may be cleared if necessary by a revolving screw inside. Air is supplied by the natural draught of the furnace. In the experiment three-quarters of a barrel of oil was burnt in 1½ hour for a heat of 500 lbs., but probably less oil would be required if the apparatus were less crude.

* *Transactions of the American Institute of Mining Engineers*, vol. xvii. pp. 807-808.
† *Ibid.*, vol. xvii. pp. 808-809.
‡ *American Manufacturer*, vol. xlv. No. 7.

Bitumen.	Earthy Matter.	Vegetable Matter.	Water.
39·83	33·99	9·31	16·87

Mr. H. Wurtz * ascribes the origin of asphalts mainly to the polymerisation of certain constituents in rock oils under the influence of air, light, heat, or by the presence of saline and other matters. The theory of oxidation and inspissation is rejected. The author gives an account of several polymers, and the way in which they can be produced in support of his view.

V.—*NATURAL GAS.*

Coal and Natural Gas.—The future of coal and natural gas is discussed by Dr. J. S. Newberry.† All oil and gas wells are situated in sedimentary rocks, and are in close relations with carbonaceous deposits. The oil and gas wells of Burkesville, Kentucky, Lima, Ohio, Enneskillen, Collingwood, and Canada are supplied from the bituminous shales and limestones of the Lower Silurian age. The wells of West Virginia, New York, and Pennsylvania are supplied from the bituminous shales belonging to the Devonian system. The oil wells of Mecca and Grafton, Ohio, derive their supply from the Berea grit overlying bituminous shale of the Lower Carboniferous age. Oil wells of Colorado are sunk in bituminous shales of the Cretaceous system. No oil is found in areas underlain by crystalline rocks, or in volcanic areas, which tends to disprove Mendeléeff's theory of its origin.

The history of the petroleum industry shows that every oil well has but a limited term of service. The current production is so slow that it is a negligable quantity. What is true of oil districts will probably be true of gas-producing districts also. From this the author infers that oil and gas are not likely to supersede coal.

Natural Gas of Fayette County.—Two large gas wells have recently been opened up in Fayette County ‡ and show no signs of failing. Preparations are being made to pipe the gas to Pittsburgh, and boring in several parts is being rapidly pushed forward.

Natural Gas at Muncie, Indiana.—There are thirty-three natural gas wells in operation near Muncie, Indiana.§ The average yield of

* *The Engineering and Mining Journal*, vol. xlviii. pp. 73, 74.
† *American Manufacturer*, vol. xlv. No. 11.
‡ *Connellsville Courier*, through *American Manufacturer*, vol. xlv. No. 4.
§ *Iron Age*, vol. xliii. p. 486.

Water Gas in the United States.—The methods of production and the plant used for the production of water gas in the United States have been very fully dealt with by Mr. A. C. Humphreys.* The author has mainly devoted himself to the consideration of water gas for illuminating purposes. Two methods are chiefly used for the production of water gas, the intermittent process, in which air and steam are forced alternately through the fuel, and the continuous method, in which the decomposing carbon is heated by external means, or in which mingled steam and air are forced through the incandescent fuel.

The history of the subject is traced from the writings of Fontana in 1780 to the present time, and about a hundred patents which have been taken out since 1823 are enumerated and discussed. Mention is made of the conflicts between water gas and coal gas in the United States. In 1874 practically no water gas was made in the States or in Canada; but, at the present time, out of 1150 gas works, 300 are on the water gas system. The theory of the process is considered in detail, and the distribution of heat throughout the reactions is calculated.

The present capacity of the water gas works at Jackson, Michigan,† is about 600,000 cubic feet per day, which is delivered at 15 pence per 1000 cubic feet. Coal slack is first coked in gas retorts heated by crude petroleum, during which 6500 feet of coal gas is obtained per ton. The coke is then transferred by shoots to two adjacent generators, where its temperature is raised to 2500° F. by air blast in two minutes. It gives 115,000 feet of producer gas, which is used for raising steam at 100 lbs. pressure. About 30,000 feet of water gas is produced for each ton of slack, and is mixed with the coal gas before purification.

The cost of coal slack is 8s. 11½d. per ton, and the oil costs 2s. 0½d. per barrel of forty-two gallons. Twenty-three gallons of oil are used for heating, so that material costs 3·375d. per 1000 cubic feet. Labour costs 1·75d. in winter, and 2·65d. in summer per 1000 feet. Including interest, &c., the total cost falls below 12½d. per 1000 feet. Steel pipes are used for distribution. Sixty feet of gas supplies one horse-power to a gas-engine per hour, and it is stated that 20,000 cubic feet is the equivalent of a ton of anthracite.

Loomis Water Gas.—According to Mr. R. N. Oakman, jun.,‡ at the John Russell Cutlery Works, Turner's Falls, the daily output of

* Paper read before the Mechanical Science Section of the British Association (Newcastle Meeting).

† *Chicago Tribune*, through *American Manufacturer*, vol. xlv. No. 1.

‡ *Journal of Gas Lighting; American Manufacturer*, vol. xlv. No. 4.

into chequer-work chambers. The arrangement of these chambers is similar to that generally adopted.*

The Taylor Gas-Producer.—The gas-producer designed by Mr. W. J. Taylor has a revolving flat circular bottom, which, in its revolution, discharges the ash and clinker over its edge into a sealed ash-pit. A mixture of air and steam is used, the conduit for air and steam acting as a central support on which the bottom revolves. A Körting jet steam-blower is employed. It is stated that one ton of buckwheat anthracite will yield, in this producer, 166,000 cubic feet of gas, affording about 135,000 heat units per 1000 cubic feet. The composition of the gas produced is as follows:—

	Per cent.
Carbonic oxide	23·0 to 27·5
Hydrogen	15·0 „ 10·5
Marsh gas	1·0 „ 2·0
Carbonic anhydride	1·0 „ 3·0
Nitrogen	60·0 „ 58·0

The producers are constructed in sizes from 4 to 6 feet in internal diameter, and will convert into gas from 2½ to 5 tons of coal in 24 hours.†

VII.—*COAL MINING.*

Coal Mining in Nova Scotia.—A very full account is given by Mr. E. Gilpin ‡ of the coal-mining industry in Nova Scotia. The first notice of coal was not published until 1672, though the outcrop on Cape Breton is visible at sea for miles. In 1711 considerable amounts were taken away, and in 1720 the first regular mining operations were begun. An interesting account is given of the history up to the present time. Nova Scotia coal sales from 1785 to 1887 are shown by decades in the following table:—

Year.	Tons.	Year.	Tons.
1785 to 1790	14,349	1841 to 1850	1,533,798
1791 to 1800	51,048	1851 to 1860	2,399,829
1801 to 1810	70,452	1861 to 1870	4,927,339
1811 to 1820	91,527	1871 to 1880	7,377,428
1821 to 1830	140,820	1881 to 1887	8,992,226
1831 to 1840	839,981	Total for 1887 only	1,519,684

* *Iron Age*, vol. xliv. p. 124.
† *Ibid.*, vol. xliii. p. 805, 1 illustration.
‡ *Transactions of the Canadian Society of Civil Engineers*, vol. ii. pp. 350–400.

it is limited by the speed at which the tubs can run down. The tubs hold from ½ to 1¼ ton of coal.

After referring to the means for transportation, the author refers to the prices of labour. In the Pictou and Cumberland districts the bords are driven level, but in the flatter Cape Breton seams advantage is taken of the cleat. The coal is holed under for 3 or 4 feet, and a shot in the upper fast corner brings down the coal. In the thicker seams a layer of 3 to 4 feet is taken off near the roof, and then the rest of the coal is lifted in two benches. Tabulated statements are given of the number of men employed, with their average production, and of the total output and costs in each colliery.

Fuller details are given of the Springhill Collieries in the Cumberland district by Mr. R. W. Leonard.* This mine is worked by the bord and pillar system with the balances mentioned above. A heavy fault occurs in the seam, and is shown on plans accompanying the paper. A 6-inch bore hole, 600 feet deep, has been put down for conveying power into the mine. For this purpose compressed air will probably be used.

Anthracite Mining.—The adoption of the longwall system in American anthracite mines is strongly urged by Mr. W. S. Gresley.† By the present pillar and stall system some 40 to 50 per cent. of the entire seam is lost. When the coal lies at a moderate angle, and is fairly free from faults, basins, and such like, especially when the seams are thick, or lie close together, then the longwall withdrawing system is certainly applicable. The author describes the longwall system in detail, giving plans and sections. The great advantages of the system, and its adaptability to many seams now being worked, are pointed out, and estimates are given of the cost.

Longwall Working at the König Colliery.—J. Sprenger‡ gives a lengthy description of the method of longwall working that has been adopted at the König Colliery, at Neunkirchen (Saarbrücken). The advantages presented by this system, used in conjunction with self-acting planes, are considerable. The transport of refuse at the surface is dispensed with, and the coal may consequently be raised more rapidly. The purchase of land for the extension of the spoil

* *Transactions of the Canadian Society of Civil Engineers*, vol. ii. pp. 404–413.
† *The Engineering and Mining Journal*, vol. xlviii. pp. 136–140.
‡ *Berg- und Hüttenmännische Zeitung*, vol. xlviii. pp. 295–298, 305–308.

and r = radius of spiral. Substituting this value in equation (1) it becomes

$$(r + dr)\left(\frac{M}{r} - w\sqrt{dr^2 + r^2dv^2}\right) = (r - dr)\left(\frac{M}{r} + w\sqrt{dr^2 + r^2dv^2}\right)$$

which reduces to

$$\frac{Mdr}{r} = rw\sqrt{dr^2 + r^2dv^2}.$$

Squaring it becomes

$$\frac{M^2dr^2}{r^2} = r^2w^2\,(dr^2 + r^2dv^2).$$

or

$$r^4dv^2 = \left(\frac{M^2}{r^2w^2} - r^2\right)dr^2$$

$$\therefore\ r^2dv = dr\sqrt{\frac{M^2}{r^2w^2} - r^2} \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

whence

$$dv = \frac{dr\sqrt{\frac{M^2}{r^2w^2} - r^2}}{r^3} = \frac{dr\sqrt{\frac{M^2}{w^2} - r^4}}{r^3}$$

and

$$\int dv = v = \int \frac{dr\sqrt{\frac{M^2}{w^2} - r^4}}{r^3}$$

Integrating this the author obtains—

$$v = -\frac{\sqrt{\frac{M^2}{w^2} - r^4}}{2r^2} - \frac{1}{2}\sin.^{-1}\frac{wr^2}{M} + \text{constant}$$

$$\text{If } v = \int_{r=a}^{r=a} dv \text{ then } v_{r=a'}^{r=a} = \frac{\sqrt{\frac{M^2}{w^2} - a^4}}{2a^2} - \frac{\sqrt{\frac{M^2}{w^2} - a'^4}}{2a'^2},$$

$$+ \frac{1}{2}\sin.^{-1}\frac{wa^2}{M} - \sin.^{-1}\frac{wa'^2}{M} \quad . \quad . \quad . \quad . \quad . \quad (3)$$

For ordinary values of a and a', the last two terms may be neglected, on account of their smallness. By substituting different values for a and a' in (3), and making $v = 2\pi n$, and solving with respect to the number of revolutions n, a curve may be plotted which will show the value of the radius for various numbers of revolutions, and will represent an outline section of the drum fulfilling the conditions of the pro-

Lighting in mines consists of two kinds—lighting by fixed and by portable lamps. The use of portable lamps underground is greatly to be preferred, as there is more danger of breaking the switches or the insulation of the cables in permanent installations. Mention is made of the various forms of lamps and also of fire-damp indicators. When there is already a good electric plant, there are certain advantages in the use of lamps with secondary batteries, but in all other cases a good primary lamp is preferable. It cannot be said, however, that a really good and practical primary lamp has yet been devised.

Signalling in mines by the aid of electricity is made use of with great advantage, and only a simple code is required. Work in the shaft is easily controlled by a system of electric signals.

Machine boring and mechanical cutting are also performed by electric motors. The operation of boring by percussion with electricity offers great difficulties, but some interesting experiments have already been carried out in the United States. The application to rotary boring is easier. Electrical cutting machines, too, have already been successfully tested, notably the Bowes, Blackburn and Mori, and the Lechner machines.

Electrical Transmission of Power for Mining.—When weight is an object, according to Mr. A. T. Snell,* one horse-power per 70 lbs. of motor can be developed, but it is preferable to employ 100 to 120 lbs. After referring to the Normanton plant, the author describes the hauling and pumping plant at Llanerch Colliery, near Pontypool, Monmouthshire. For operating a single rope hauling engine by electricity the dynamo on the surface is driven by a horizontal engine with 18-inch cylinder and 3½-foot stroke, running at 50 revolutions, with a steam pressure of 50 to 60 lbs. The current is conveyed by a copper cable of 19 strands No. 18 BWG, insulated and covered with lead. The motor is situated 750 yards from the pit, which is 250 yards deep. The haulage is effected by an old type machine previously driven by a single engine but now converted. Two drifts are worked with inclines of 1 in 8 and 1 in 12 respectively, and each is about 300 yards long. A loaded tram weighs 29 cwt. Signals are given by a "rapper." Testing instruments show the driver if the tram is off the line, and give him warning of other accidents. The rolling friction on the road averages 70 lbs. per ton, and about 5 horse-power is absorbed by the

* Lecture at the Mining School, Wigan, *Iron and Coal Trades Review*, vol. xxxix. pp. 455–456.

ticulars of the electric light installation at the Corsall Colliery, Newark. Excluding labour, the cost is reckoned at £61 for 222,000 lamp hours, the lamp giving a light of 16 candle-power. The cost is made up as follows:—Coal, £8, 5s.; renewals of lamps, £27, 15s.; interest and depreciation, £20; oil, waste, &c., £5. Under similar conditions, gas is estimated to cost £150. A list is given of forty-six collieries now using the electric light.

Mr. A. F. Guy * gives the approximate cost of lighting a colliery 400 feet deep. The plant consists of 75 glow-lamps of 16 candle-power, burning 9000 hours, and two arc lamps of 1000 candle-power each on the surface, burning for 500 hours. The cost of the plant is given as £269, and the annual working cost is £93, taking coal at 5s. per ton, interest 5 per cent., depreciation 10 per cent., and labour, &c., £20.

An electric miner's lamp with a primary battery has been described by Mr. E. T. Boston.† The cell is of guttapercha, and the elements are zinc and carbon. The lamp is placed on the top, under a thick glass dome, so as to cast no shadow on the roof. The weight is 2¼ lbs., cost one penny per shift when giving 2½ candle-power for ten hours, and the total first cost need not be more than £1.

Safety Lamp Experiments.—A report of the committee appointed to carry out a series of experiments on lamps at the Cymmer Colliery, Rhondda Valley, has been published.‡ The safety of the shielded Clanny lamp was tested in various currents of explosive mixture. Gas from a blower was used, and maintained at an even pressure in a holder whence it was delivered with air at a distance of 9 feet from the lamps. At this distance the admixture of air and gas was perfect. The mixture used contained 9·5 per cent. of gas in all cases. Several varieties of lamps were tested, none of which did the committee feel themselves justified in recommending. The two-thirds shielded Clanny is pronounced to be unsafe in the high velocity of the air currents in the Rhondda district.

Safety Lamps.—At the Mining and Metallurgical Congress recently held at Paris, M. H. Le Chatelier reviewed the present status of some of the more important lamps, and his report was followed by a vigorous discussion. M. Fumat showed an improved form of his

* *The Colliery Guardian*, vol. v. p. 143.

† *Proceedings of the South Wales Institute of Engineers*, vol. xvi. pp. 266-267, with plate.

‡ *Iron and Coal Trades Review*, vol. xxxviii. p. 622.

experiments with roburite at the Park Lane collieries and elsewhere. They conclude that there are undoubted cases of nitro-benzene poisoning arising from improper manipulation of the cartridges, that roburite undergoes complete combustion if properly confined, but that there is a chance of incomplete combustion if the explosive does not meet sufficient resistance, that carbonic oxide is produced by the action of the heated gases on the coal, and that this carbonic oxide may be the cause of headache complained of. The committee recommends that the entire manipulation of the cartridges should be entrusted to shot-firers properly instructed in their use; that the effective tamping of the cartridges should be insisted on; that the fumes should be removed as quickly as possible by advancing the brattice cloth, and that they should be speedily mixed with large volumes of air.

A further committee was appointed by the Lancashire Miners' Federation to deal with the above report.* It was concluded that the report showed the extreme danger of using roburite, and that, therefore, its use should be discontinued.

Experiments recently made with carbo-dynamite show that it is superior to ordinary dynamite in the work performed, besides which no noxious fumes were observed. It was concluded that No. 1 carbo-dynamite was equal to blasting gelatine, and No. 2 quality to No. 1 ordinary dynamite. The explosive can be fired successfully after soaking in water.†

The subject of explosives generally is fully treated by Mr. P. F. Nursey ‡ and by Mr. C. N. Hake.§

Experiments have been made with tonite at Melling, near Ormskirk, to show that Trench's fire-preventing compound prevented flame and explosion.‖

In some experiments made with carbonite at the Nunnery Colliery, one charge of six ounces brought down twelve tons of coal, the cost of the explosive being 4½d., as compared with 3d. for powder, but, on the other hand, no flame was observed, and the charge of carbonite was rather too heavy.¶

Favierite consists mainly of ammonium-nitrate and mononitro-naphthalene, but sometimes dinitro-benzene or other nitro-hydrocarbon is

* *Iron*, vol. xxxiv. p. 75.
† *Ibid.*, pp. 25-26.
‡ Paper read before the Society of Engineers.
§ *The Journal of the Society of Chemical Industry*, vol. viii. pp. 518-525.
‖ *The Iron and Coal Trades Review*, vol. xxxix. p. 233.
¶ *Ibid.*, p. 427.

The following table shows the relative degree of safety for colliery purposes of the more important explosives in ordinary use :*—

	Fires regularly.	Fires occasionally.	Never fires.
0·66 lb. explosive ; clay tamping ; coal-dust present but no gas.	Ordinary powder Carbo-dynamite Blasting gelatine	Gelatine-dynamite Kieselguhr-dynamite Roburite	Securite Favierite Carbonite Fire-damp dynamite Ammonia-dynamite Water cartridges
0·66 lb. explosive ; clay tamping ; both coal-dust and gas present.	Ordinary powder Carbo-dynamite Blasting gelatine	Gelatine-dynamite Kieselguhr-dynamite Roburite	Securite Favierite Carbonite Fire-damp dynamite Ammonia-dynamite Water cartridges
0·22 lb. explosive ; no tamping ; coal-dust present, but no gas.	Ordinary powder Carbo-dynamite Blasting gelatine Gelatine-dynamite Kieselguhr-dynamite	Roburite	Securite Favierite Carbonite Fire-damp dynamite Ammonia-dynamite Water cartridges
0·66 lb. explosive ; no tamping ; coal-dust present, but no gas.	Ordinary powder Carbo-dynamite Blasting gelatine Gelatine-dynamite Kieselguhr-dynamite Roburite Securite	Fire-damp dynamite	Favierite Carbonite Ammonia-dynamite Water cartridges
0·66 lb. explosive ; no tamping ; both coal-dust and gas present.	Ordinary powder Carbo-dynamite Blasting gelatine Gelatine-dynamite Kieselguhr-dynamite Roburite Securite	Fire-damp dynamite Ammonia-dynamite	Favierite Carbonite Water cartridges

Coal Transfer.—The usual method of transferring coal from the trucks to barges on the Ohio appears to be by baskets lowered vertically. In some cases, the truck itself is lowered bodily. Whatever arrangement is adopted, all kinds of trucks must be accommodated, the coal must be handled gently, and should preferably be carried, and not allowed to grind over itself and the sides and bottom of the shoot. The barge should be loaded uniformly to avoid strains and leakage.

* *Zeitschrift für das Berg- Hütten und Salinenwesen*, vol. xxxvii. Table C.

fixed in the coaling vessel. As an illustration of the first system, a plant recently erected in Venezuela was described. A steel framework, 65 feet high, and travelling on rails, is used for raising the truck, which is then tipped and returned in three minutes. Drawings are given of floating elevators, &c.

VIII.—*COAL-WASHING.*

Banking-out and Screening Plant at East Hetton Colliery.—According to Mr. S. Tate,* it was decided to reconstruct the pit heap and screening plant of the upcast shaft at East Hetton Colliery, so that the greatest amount of mechanical power could be utilised. In the scheme adopted, after the full tub has been emptied, it runs by force of gravitation to a point where it is taken to the other side of the shaft by mechanical power. The coals are tipped into a jigging screen where they are sorted into three kinds—(1) best, (2) nuts, and (3) peas and duff. The best coals are carried along a travelling belt, and the stones, &c., picked out by boys placed along each side. The nut coals are delivered out at the side of the jigging screen on to a belt running parallel with the best coal belt, but at a different angle. After the stones, &c., are picked out, the coals are delivered over a set of screen bars or gauzes, by which the treble and double nuts are separated into their respective waggons. The peas and duff coals drop out at the bottom of the jigging screen on to a smaller belt running in a direction contrary to the other belts, and which carries the coals to an ordinary "Beeswing" elevator. In this manner, the coals are much better cleaned, and at a very much less cost than was formerly the case. The advantages derived from this system of banking-out and screening may be summarised as follows:—1. Cheapness of labour cost, consequent on utilising mechanical power. 2. Cheaper class of labour employed. 3. Coals are better cleaned, and with less breakage.

Illustrations and description of the elaborate plant for handling and washing coal, belonging to the Commentry Fouchamboult Company, are given in *Le Génie Civil.*

Mechanical Slate Picker.—A very simple form of apparatus for separating slate from coal has recently been exhibited. A shoot with

* *Transactions of the North of England Institute of Mining Engineers*, October 12, 1889.

a sheet iron bottom is placed beneath the screens, and is ridged transversely at intervals. Just beyond the ridge is a transverse cloth, 6 to 8 inches wide, and adjustable in width by a sliding plate. The coal and slate slide down the shoot; the slate, as it is heavier and rougher than the coal, is somewhat arrested by the ridge, and so falls through the opening beyond, but the coal, being lighter and more glassy, gathers enough impetus to jump over the opening and pass to the bunkers.*

Weight per Cubic Foot of Broken Anthracite.—Experiments have been made under the direction of Mr. J. W. Bowden † to determine the actual weight per cubic foot of anthracite broken to different sizes. Susquehanna Coal Company's anthracite was used in proportions and with results as follows:—

			Lbs.
45	per cent.	Mill's seam, average weight per cubic foot,	90·46
15	,,	Twin ,, ,, ,, ,,	92·20
25	,,	Ross ,, ,, ,, ,,	93·00
15	,,	Buck Mountain ,, ,, ,,	94·75
100	,,	mixed coal ,, ,, ,,	92·00

Space filled as loaded at breaker without settling. Add 5 per cent. for packed spaces or large heaps.

Size.	Size of Mesh in Inches.		Weight per Cubic Foot.	Cubic Foot from 1 Cubic Foot Solid.
	Over.	Through.	Lbs.	
Lump		..	57	1·614
Broken		3¼–4½	53	1·755
Egg		2¼–2¾	52	1·769
Large stove		1¾–2¼	51½	1·787
Small stove		1¼–1½	51¼	1·795
Chestnut		1 –1¼	51	1·804
Pea		½– ¾	50¾	1·813
No. 1 buckwheat		¼– ½	50¾	1·813
No. 2 buckwheat	...	$\frac{1}{16}$– ¼	50¾	1·813

* *The Canadian Mining Review*, vol. viii. p. 52.

† *The Engineering and Mining Journal*, vol. xlvii. pp. 496–497.

PRODUCTION OF PIG IRON.

CONTENTS.

I.—*BLAST FURNACE PRACTICE.*

Result of Blast Furnace Practice with Lime as Flux.—Sir L. Bell has given the maximum ratio of carbonic oxide to carbonic anhydride in gases escaping from the blast furnace as one to two by volume or three to four by weight. The maximum efficiency of the furnace has been calculated by M. Gruner with these data. Probably these figures are correct under certain conditions, but Mr. C. Cochrane* shows that unrecorded conditions affect this result. The two leading features are the combustion of carbon to carbonic oxide at the tuyeres, and the reaction of this gas on oxide of iron as shown by the formula $Fe_2O_3 + 3CO = Fe_2 + 3CO_2$. Assuming that 15 cwt. of pure carbon produces 20 cwt. of pure iron, there is 35 cwt. of carbonic oxide produced at the tuyeres, and, according to the above formula, 15 cwt. of carbonic oxide is required to reduce the iron, giving 23·57 cwt. of carbonic anhydride. The ratio of carbonic anhydride to carbonic oxide thus becomes 23·57 to 20·00 or 1·18 to 1. As a matter of fact Sir Lowthian Bell's ratio of 0·75 has not been attained in Cleveland furnaces, but the author proposes to show that the reason is to be found in the reaction of red-hot coke on carbonic anhydride.

In the blast furnace red-hot coke will reduce the carbonic anhydride. One unit of carbonic anhydride by reduction to carbonic oxide requires 5607 heat units or the combustion of $5607 \div 2473 = 2·26$ units of carbon; one unit has disappeared in the process, so 1·26 unit

* *Proceedings of the Institution of Mechanical Engineers.*

extra has to be burnt at the tuyeres, and there is a total loss of efficiency of 2·26 units. When limestone is employed as a flux, it acts as one source of carbonic anhydride, and the reduction of iron oxide acts as the other. The reduction of the ore should take place at a point above that where the temperature is great enough to decompose the flux. If the ore plunges down to the red-hot region before decomposition so that the resulting carbonic anhydride is all decomposed again by coke, there may be an increased consumption of 13·65 cwt. of carbon per ton of pig iron at the tuyeres. In order to economise in this direction, the furnaces at Middlesbrough were increased in size to give greater time for reduction. Analyses of the gases from these high furnaces show slightly more carbonic anhydride than can be accounted for by the reduction of iron, and this must proceed from the limestone. The amount, however, is small, and does not affect the main question.

An elaborate comparison is then made by the author between the results obtained from a furnace working under two different conditions.

	Working on Limestone.	Working on Lime.
Ratio of CO_2 to CO by weight	0·473	0·535
Temperature of blast	807° C.	765° C.
Temperature of escaping gases	327° C.	301° C.
Coke consumed per ton of pig iron	23·28 cwt.	19·49 cwt.
Limestone consumed per ton of pig iron	13·18 „	12·28 „
Total weight of dry air required per ton of pig iron	114·05 „	87·69 „
Total weight of dry gases escaping	146·23 „	113·10 „
Consumption of calcined ironstone per ton of iron	50·13 „	50·00 „
Make of pig iron per month	2141 tons	2453 tons
Quality of pig iron. No.	3·25	3·31
Blast, pressure per square inch at tuyeres	3·87 lbs.	3·73 lbs.
Area of tuyeres in square inches	142	142

The economy in pure carbon in the coke is 21·19 − 17·44 = 3·75 cwt. per ton of pig iron, whereas by calculation on the lines indicated above the saving should have been 2·94 cwt., according to the composition of the escaping gases. The ratio of carbonic anhydride to carbonic oxide has not been raised so much as was hoped, and in this the use of lime has failed to accomplish all that was desired, for the weight of carbonic anhydride of reduction has been diminished. The causes of this disappointment are twofold. When limestone is used its carbonic anhydride is reduced to oxide, and so the activity of the

the furnace through the tuyere slagging valves attached to the belly-pipes. These valves are operated by air-cylinders and are opened and closed with the engine running, and the slag can be discharged without any risk or loss of time. After about twenty-four hours of close attention and hard work, the furnace was again in fair working order. An examination showed that the brickwork on the west side of the furnace about the top of the boshes was only 2 to 3 inches thick, whilst on the east side it was 9 to 10 inches. This was determined by drilling holes at intervals through the furnace walls. In order to fill up and restore the bosh to something approximating suitable proportions, it was decided to run the furnace on silver-grey iron, in hopes that a graphitic bosh could be formed. It was while this effort was being made that the samples of unreduced ore were obtained from the tuyeres on the east side. It was observed that the tuyeres on the west side worked much better and brighter than those on the east side. The temperature was experimentally determined by driving bars of wrought iron into the centre of the furnace through the plug-holes of the several tuyeres. On the west side the bars became white-hot and melted off before they could be drawn out, whilst on the east side similar bars were bright red at the points, and only dull red for the greater part of their length. About the same time the tuyeres on the east side were rapidly cut, exploding with reports similar to pistol shots. As these tuyeres were removed the stock in front of them was taken out and preserved. It was from this stock that the specimens of unreduced ore were selected. At this time the stock was passing through the furnace in about sixteen to eighteen hours, and the iron made was chiefly No. 1. The slag was uniform and hot, and the furnace was working fairly regularly, but not with the usual fuel economy or average yield of iron. Owing to the shape of the furnace being oblong, instead of circular, it was supposed that a much larger volume of gas ascended on the west side than on the east. The gas currents thus established thoroughly reduced the ore on that side, but were deficient in quantity on the east side, and thus the ore on this side descended without being properly acted upon, and reached the tuyeres and crucible unreduced. The presence of unreduced ore naturally made that side of the furnace work cold, and this again facilitated still further arrivals of unreduced ore in the crucible. The frequent loss of tuyeres was due to the formation of pockets under the tuyeres, which filled with iron as it was melted, and this iron coming into contact with the bronze of the tuyeres produced the explosions. In order to

The pig iron made from these ores has the following composition :—

	Foundry Iron.	Grey Forge Iron.	White Forge Iron.
	Per cent.	Per cent.	Per cent.
Carbon	4·00–4·50	3·50–4·00	3·00–3·50
Silicon	2·50–3·00	0·50–0·95	0·20–0·60
Sulphur	trace–0·05	0·03–0·07	0·04–0·06
Phosphorus	0·40–0·80	0·40–0·80	0·40–0·85
Manganese	0·60–0·90	1·00–1·50	0·80–1·00

The slag produced has the following composition :—

	Foundry Iron.	Grey Forge Iron.	White Forge Iron.
	Per cent.	Per cent.	Per cent.
Silica	31·50–32·00	29·50–30·00	29·50–30·00
Alumina	23·50–24·00	21·50–22·00	22·50–23·00
Lime	43 50–44·00	47 50–48·00	46·50–47·00

By the addition of manganese ores from Laurium in Greece, or Romanêche, France, the following metal is produced :—

Carbon.	Silicon.	Sulphur.	Phosphorus.	Manganese.
3·50–4·00	0·10–0·35	trace–0·03	0·40–0·75	4·50–5·00

The slag then produced contains :—

Silica.	Alumina.	Lime.
27·00–27·50	21·00–21·50	51·00–51·50

About 3 millions of slag bricks are produced annually at this works.

At the Firminy Steelworks there is one blast furnace with a daily production of about 90 tons. The following are analyses of ores smelted :—

The following are analyses of the pig iron and spiegeleisen produced:—

	Carbon.	Silicon.	Manganese.	Phosphorus.	Sulphur.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Foundry iron	3·40	3·20	0·10	0·07	0·02
White forge iron . .	3·20	0·40	1·02	0·07	0·07
Silicon-spiegeleisen .	1·42	17·00	18·09	0·085	trace
Spiegeleisen	4·00	4·50	15·00	0·07	0·01

At the St. Louis Works, Marseilles, metals of the follow composition are produced:—

	Fe.	Mn.	Total Carbon.	Graphite.	Si.	S.	P.	Cu.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.
Spiegeleisen . .	65·80	27·41	6·00	0·28	0·23	0·009	0·062	0·019
Ferromanganese	47·14	46·19	5·93	0·14	0·14	0·005	0·095	0·024
Ferromanganese	6·23	85·40	7·10	0·56	0·47	trace	0·168	0·060
Ferrosilicon . .	82·60	2·50	2·10	2·10	12·60	0·054	0·088	trace

Both foundry and forge pig iron are also made at this works.*

French Blast Furnaces.—The following are the dimensions of two blast furnaces erected at Micheville, France:—

	I.		II.	
	Feet.	Inches.	Feet.	Inches.
Height	67	7	67	7
Diameter at crucible . . .	6	7	7	6
Diameter at boshes . . .	21	4	22	2
Diameter at throat . . .	17	3	18	1
Capacity, cubic feet . . .	15,892		16,775	

No. 1 furnace was put into blast in 1878, foundry iron being made, the outturn being from 80 to 90 tons. White iron was afterwards made in place of the foundry iron, and the production increased to 120 tons. The blast is heated by six Whitwell stoves, each 49 feet 2 inches in height, but these are now being replaced by Cowper stoves.†

* *Stahl und Eisen*, vol. ix. p. 858.
† *Ibid.*, p. 856.

The Blast Furnaces at the Isbergues Steelworks, France.—F. Laur * states that the main dimensions of the two blast furnaces erected at these works are as follows:—

	Feet.	Inches.
Height	65	7
Diameter at the boshes	19	8
Diameter at the throat	14	8
Diameter at the crucible	7	4

The capacity is about 12,360 cubic feet.

Somorrostro ore is alone used, the percentage of sulphur not exceeding 0·04, and that of phosphorus 0·05. The daily production of the furnaces is about 260 tons, with a consumption of 495 tons of ore, 95 tons of limestone, and 265 tons of coke. The blast is heated in twelve Whitwell stoves to a temperature of 750°, the pressure being usually about 9½ inches, reaching occasionally 11 inches.

Russian Ironworks.—Professor Time, of the St. Petersburg Mining Institute, has prepared an elaborate report on the present condition of the metallurgical and mining industries of the Don coalfield. This has been translated from the Russian by Mr. G. Kamensky.†

The author first describes the oldest of the South Russian ironworks—those of Mr. Hughes. They are typical English works, with two blast furnaces. It is now proposed to build a third, capable of yielding 160 tons per day. The life of the old coke furnaces having a yield of 25 to 30 tons per day often exceeded nine years, or about 110,000 tons during the whole period. Under present conditions at Hughes' works a furnace is capable of yielding 100,000 tons during its four years' life. Mr. Hughes is of the opinion that a shorter life with a corresponding increase in production is still more profitable, and that 150,000 tons of iron may be smelted in two or three years with great advantage.

The Hughes works possess both a puddling and a steel-making department. The former consists of eight open-hearth furnaces and a three-high rolling mill. The yearly production of rails is nearly 30,000 tons. The open-hearth process takes twelve hours. The furnace charge is composed of 10 tons of pig iron, 5 tons scrap iron, ½ ton spiegeleisen, and a small quantity of Krivorogesky iron ore. The metal is run into a cast iron mould. The ingots have a section of 14 inches square at the wide end, and 12 inches at the narrow end. Their

* *L'Écho des Mines* vol. xiv., No. 41, p. 5.

† *The Colliery Guardian*, vol. lvii. p. 876; vol. lviii. pp. 24, 83, 132, 241.

weight varies from 1 ton to 1¼ ton. Each ingot makes four rails. One ton of rails requires the consumption of ½ ton of coal in the open-hearth furnaces, and ¾ ton for reheating and working the rolling mills.

The number of men employed at the works and in the mines is 4000. The amount paid in wages varies from £15,000 to £18,000 per month. The production of the Hughes ironworks during the year 1888 amounted to 53,704 tons of pig iron, 26,877 tons of steel rails, 4224 tons of chairs, fish plates, &c., and 4750 tons of manufactured iron. Of coal, 263,730 tons were raised, and 67,708 tons of coke were produced. The following are analyses of the material used:—

	Belokrisensky.	Ingouletzsky.	Terenashinsky.	Lifmansky.
Fe_2O_3	92·14	91·42	92·48	95·70
SiO_2	5·96	5·74	3·75	1·00
Al_2O_3	0·50	0·30	1·00	7·00
P_2O_5	0·04	0·067	0·10	0·024
S	0 027	0·025	...	0·014
Mn	0·264	...	...	...
CaO	...	0·560	...	0·54
Metallic iron	64·50	64·00	64·63	67·00

	Novotroensky Ore.	Nicolaeffsky Ore.	Stileffsky Ore.			Karakoubsky Ore.			
			No. 2.	No. 116.	No. 4.	No. 5.	No. 51.	No. 7.	No. 8.
Fe_2O_3	76·14	71·43	71·43	70·00	64·24	73·00	73·00	76·14	73·00
SiO_2	8·70	17·50	12·00	20·00	16·00	13·30	14·40	7·50	8·00
Al_2O_3	5·00	4·00	5·98	5·00	8·00	...	...	3·50	3·10
S	...	...	...	...	...	...	...	...	...
P_2O_5	1·00	0·438	0·13	0·25	0·09	0·10	0·115	0·167	0·77
Mn	...	...	4·00	...	8·00	...	...	...	...
CaO	2·35	0·335	...	...	...	...	...	3·00	7·90
Metallic iron	53	50	50	49	45	51	51	53	51

Coals from the Smolianinoffsky Seam.—An assay of coal after being three days in a room at 17° C. gave the following percentages:—Ash, 2·56; sulphur, 0·35; coke, 79·07; non-volatile organic matter, 75·93; volatile matter, 20·75; moisture, 1·0. Dried over sulphuric acid during four days the coal yielded:—Ash, 2·59; sulphur, 0·36; disposable hydrogen, 3·14; nitrogen and oxygen, 10·60; hydrogen, 4·46; carbon, 81·99. Specific gravity, 1·298; calorific power calculated from analysis 7690 calories; evaporating power, 14·32; 100 parts of the organic

matter of the coal yielded: volatile matter, 21·60; coke, 78·40; carbon, 84·48; hydrogen, 4·57; oxygen and nitrogen, 10·95.

Coal from the Livensky Seam.—From 100 parts of coal, after being three days in a room at 17° C., there was obtained:—Ash, 3·59; sulphur, 0·72; coke, 72·25; non-volatile organic matter, 68·50; volatile organic matter, 26·86; moisture, 0·89. In 100 parts of coal, dried over sulphuric acid during four days:—Ash, 3·63; sulphur, 0·73; disposable hydrogen, 3·30; nitrogen and oxygen, 12·45; hydrogen, 4·86; carbon, 78·33. Specific gravity, 1·300; calorific power, 7451 calories; evaporating power, 13·87.

Coal from the Semeonoffsky Seam.—100 parts, after being three days in a room at 17° C., yielded:—Ash, 3·75; sulphur, 0·66; coke, 63·70; non-volatile organic matter, 59·62; volatile organic matter, 35·01; moisture, 0·96. In 100 parts, dried over sulphuric acid during four days:—Ash, 3·79; sulphur, 0·67; disposable hydrogen, 3·33; nitrogen and oxygen, 12·32; hydrogen, 4·87; carbon, 78·35. Specific gravity, 1·292; calorific power, 7463 calories; evaporating power, 13·89.

Coke from the Smolianinoffsky Coal.—100 parts, after being three days in a room at 17° C., yielded:—Ash, 8·08; sulphur, 0·68; coke, 99·79; non-volatile organic matter, 91·03; volatile organic matter, 0; moisture, 0·21. In 100 parts dried over sulphuric acid during four days:—Ash, 8·10; sulphur, 0·69; disposable hydrogen, 0·19; nitrogen, oxygen, 1·06; hydrogen, 0·32; carbon, 89·83. Specific gravity, 1·945; calorific power, 7525 calories; evaporating power, 14·01. This coke is considered the best made in the Don basin.

Iron.—Cast iron for sale:—Carbon (graphitic), 3·595; carbon (combined), 0·511; silicon, 2·111; sulphur, 0·024; phosphorus, 0·593; manganese, 1·685. Pig iron for steelmaking:—Carbon (graphitic), 3·109; carbon (combined), 0·620; silicon, 1·810; sulphur, 0·031; phosphorus, 0·070; manganese, 0·216.

Manganese Pig.—Manganese, 45·5; carbon, 4; silicon, 1; phosphorus, 0·25; iron, 49·25.

Open-hearth Steel (Rails).—Carbon per cent., 0·400; silicon, 0·030; sulphur, 0·034; phosphorus, 0·072; manganese, 0·700.

The Alexandroffsky, or Briansk Works, as they are often called, are situated on the right bank of the River Dnieper about a mile from the town of Ekaterinoslav.

The plant of the Ekaterinoslav works is calculated for the production of 50,000 tons of steel rails and 25,000 tons of iron of various sorts. For the manufacture of the above quantity of rails and iron,

the vertical direct-acting type, having the steam cylinder below, and the air cylinder above. The steam-cylinder is 34 inches in diameter, and has a 4-foot stroke; it is fitted with a Reynolds-Corliss valve gear. The air cylinder is 78 inches in diameter, with a 4-foot stroke, and has the Reynolds patent positive-motion air valve. The two fly-wheels weigh 31 tons, and the total weight of the engine is 92 tons. The speed is controlled by a fly-ball governor attached to the cut-off cams of the steam-valve, and can be varied from 12 to 50 revolutions by simply turning a hand-wheel, the engine remaining absolutely under control of the governor. At 50 revolutions the capacity is 13,000 cubic feet of air per minute.

The special feature of the machine is the valve gear of the air cylinder, which was designed by Mr. E. Reynolds. In each cylinder head are two rolling valves, each 16 inches in diameter, one being the inlet, and the other the discharge. The inlet valves are opened and closed positively by means of a direct connection with a wrist-plate. The discharge valves are closed at the proper time by the same wrist-plate that drives the inlet valves, but are opened automatically when the air in the cylinder reaches the same pressure as the air in the blast-pipe leading to the furnace. The wrist-plate is driven by an eccentric on the main shaft of the machine through suitable connection. The connection between the wrist-plate and the delivery valve is by means of a rod slotted to receive a pin on the actuating arm of the valve, and is positive in its motion only at such time as the rod is moving towards the cylinder head and acting upon the valve to close it. When the motion of the wrist-plate is reversed, the slotted end of the rod permits the reverse motion of the wrist-plate and rod to take place, while the delivery valve remains closed, being held in that position by a hook or catch until it is automatically released and allowed to open. Attached to the stem of the valve is an arm, provided at its outer end with a pin and block, on which is also attached by pin and rod a weight working in a dash-pot. To a fixed pin is pivoted a hook provided with a tailpiece engaging with the block. The piston-rod of the piston of a small cylinder is so arranged as to disengage the hook at the proper time to allow the weight to open the delivery valve. When this valve is closed the piston-rod is free of the hook, and yet so near that a short movement will cause it to bear against and release the hook. The small cylinder is connected by a pipe in its top with the receiver or blast-pipe leading to the furnace, whilst a second pipe connects the other end with the end of the main

It is found that 3-inch valves are most convenient in size. One 6-inch valve has been made; in this case the cap itself is the valve, and carries eye-hole and pricker-hole. On one occasion the engine suddenly stopped and the pipes filled with slag. The 6-inch valve opened automatically by the pressure of the slag, the others were easily opened with a small bar. The shell of slag was cleared and everything restarted in half an hour's time. These valves are found to give perfect satisfaction, and are even opened once or twice a day to clean out the tuyeres.

Flue Dust.—A small percentage of zinc in the ores of Low Moor, Virginia, according to Mr. E. C. Means,* sometimes gives rise to trouble in working the furnaces. In one case a mass of nearly 6 tons of zinc oxide was attached to the lining below the tunnel head. A dust catcher with a small bell is used to reduce the amount in the flues. The bell is lowered at least twice, and the daily yield is 600 to 1000 lbs. An analysis gave 87·66 per cent. of zinc oxide, or 70·36 per cent. of metallic zinc. It also contained iron, manganese, lime, alumina, silica, phosphoric, and sulphuric anhydrides. An analysis of the dust taken 150 feet from the furnace showed 30 per cent. of metallic zinc.

II.—*CHEMICAL COMPOSITION OF PIG IRON.*

American Pig Iron.—According to Lagerwall,† the following are the six most notable types of pig iron made in the United States:—1. The Poughkeepsie iron, made in New York with anthracite, from two-thirds of magnetite and one-third brown hæmatite. It is especially adapted for castings, and contains approximately 4·24 per cent. of carbon, 3·00 silicon, 0·15 phosphorus, 0·05 sulphur, and 1·46 manganese. 2. The Bushong pig iron of Pennsylvania, made from similar material, and containing 3·34 carbon, 1·93 silicon, 1·09 phosphorus, 0·013 sulphur, and 0·14 manganese. 3. Pig iron made from red hæmatite at the Franklin and Alice furnaces in Alabama, with a high temperature and rapid blast, contains 4·85 silicon and only 2·96 carbon. The Rising iron of Georgia, containing 1·74 silicon and 4·23 carbon, is of good quality. In the Southern States the proportion of manganese is usually very low. 4. The Dayton pig iron is made in

* *Transactions of the American Institute of Mining Engineers*, vol. xvii. pp. 129-131.
† *Jernkontorets Annaler*, vol. xliii. pp. 361-373.

In order to produce an alloy very rich in chromium use was made at Unieux of potassium dichromate. The main difficulty connected with the economic manufacture of these alloys consists in the difficulty with which the chromium is reduced. From this cause the output of a blast furnace sank to 11 or 12 tons a day, 3 tons of coke being used for each ton of the chrome iron produced. The production of chrome-iron-manganese is, however, now very easy. H. Echardt's process,* which consists in smelting the chrome ore with cinder from the acid Bessemer converter, and with manganese ore, yields good results, the metal and slag separating with great readiness, the manganese in the alloy adding greatly to the fluidity of the metal.

When molten ferro-chrome is exposed to the action of the atmosphere it becomes covered with a green film of chromium oxide; the chromium slags, on the other hand, become covered with a brown film on cooling, due, it is thought, to the formation of a chromate.

With regard to the influence of chromium on iron, the addition of chromium to unhardened steel greatly increases the limit of elasticity and the ultimate tensile strength, without, however, affecting the degree of elongation which would be due to the percentage of carbon also present. A chrome steel may possess the same power of resistance to stress as a hard carbon steel, but it will not be so brittle. An addition of chromium by itself will not impart to iron the property of becoming hardened on quenching in water, but a chrome steel containing carbon is easier to harden and becomes much harder than does a steel with the same percentage of carbon, but which contains no chromium. Unhardened chrome steel is difficult to fracture, and shows a very fibrous structure. By hardening at suitable temperatures the texture of the metal becomes the more finely granular the higher the percentage of chromium and of carbon. When the percentage of carbon reaches 4, the metal is so hard that ordinary tools will not touch it. If, however, such steel is hardened in water, it becomes fragile. One of the peculiarities of chrome steel is that the oxide scale on the surface of the metal does not separate from the metal when it is plunged into water from a red heat. Chrome steel deteriorates in quality if it is heated to too high a temperature, or for too lengthened a period. Such steel, too, solidifies at a much higher temperature than does ordinary carbon steel, and whilst of very fine grain and extremely hard, it is more affected by sudden shock than it is by a steady stress. For certain classes of tools it is better than the very best crucible

* *Journal of the Iron and Steel Institute*, 1889, vol. i. p. 311.

sulphur when small in amount the variations are very great, and this may be due either to imperfect methods of analysis or to great variation in the distribution. Probably both aspects require consideration. As regards silicon the analysts vary about 0·1 per cent., while in the same brand the differences are 0·5 per cent. With regard to methods of analysis, many kinds were tried and gave uniform results with each individual, so that there appears to be no particular preference for one over another.

III.—*BLAST FURNACE SLAGS.*

Mica in Slag.—Professor J. H. L. Vogt,* of Christiania, has discovered mica in a melilite slag from the Königin Maria Ironworks at Zwickau in Saxony. The mineral, which was isolated by treatment with hydrochloric acid and potassium hydrate alternately, was found under the microscope to be optically negative and biaxial. Distinct pleochroïsm was observed. The author regards this variety of mica as belonging to the biotite series. He has also discovered mica in slag from Kafveltorp works in Örebro, Sweden, and from the Garpenberg works in Sweden.

A Fayalite Slag.—A. Firket † has analysed a slag from the Ougrée Ironworks with the following results:—

Silica.	Ferrous oxide.	Ferric oxide.	Manganous oxide.	Sulphur.	Phosphorus.
28·00	62·00	9·30	0·97	0·14	0·50

The sulphur being subtracted as manganese iron sulphide, and the phosphorus as iron phosphide, there remains 82·69 Fe_2SiO_4, 1·17 Mn_2SiO_4, 12·21 Fe_2SiO_5, and only 0·42 Fe_2O_3 in excess. The hardness of the slag was found to be 6, and its specific gravity 4·212.

Blast Furnace Slags.—P. Gredt ‡ has made a series of experiments to ascertain the influence exerted by the presence of varying quantities of alumina on the melting-points of blast furnace slags. The influence which is exerted on the successful working of a blast furnace by the relative fusibility or infusibility of the slag becomes

* *Forhandlinger i Videnskapsselskabet i Christiania*, No. 6, pp. 1–42.

† *Zeitschrift für Krystallographie*, vol. xv. pp. 652–653.

‡ *Stahl und Eisen*, vol. ix. pp. 756–759.

By means of these figures the author shows that the melting-points of any other mixture of silica, alumina, magnesia, and lime may be readily calculated.

Mr. A. D. Elbers * shows that the amount of sulphur in blast furnace slag is an indication of the contained silicates. Slag not containing sulphur is practically useless for manufacturing purposes, as the silica is high and the slag chills too quickly. Sulphurous slags, on the other hand, remain fluid for a longer time, but are likely to warp and to yield unsound castings which are "cold short." By the removal of the sulphur, these defects are also removed. The slag can be desulphurised by treating it in converters, while it is in the liquid state, with sodium nitrate. Other cheap fluxes may also be added to reduce the solidifying point. Each per cent. of sulphur will require about 1½ per cent. of sodium nitrate for its combustion as expressed in the equation:—

$$10\,CaS + 12\,NaNO_3 = 10\,CaO + 6\,Na_2O + 10\,SO_2 + 12\,N.$$

Sodium chloride may also prove a suitable flux, especially when it is desired to get rid of iron by chlorination. These additions tend to make the slag more fluid if the bases are not increased beyond certain limits. In this way less sulphurous slags might be profitably treated. Desulphurised slag of favourable composition might remain plastic long enough for it to be balled up and compressed into suitable forms.

Slag as Manure.—Mr. W. R. Phillips † gives the composition of several forms of basic slag and other manures containing phosphorus. He shows that, commercially speaking, the value of the slag is often equal to, and sometimes even surpasses, that of other phosphatic manures. Most of the phosphorus in the charge goes into the pig iron, and then appears in the slag. The author has calculated the ratios, and finds that to produce a slag containing from 17 to 20 per cent. of phosphoric anhydride, the charge should contain from 0·65 to 0·76 per cent. of phosphorus. On an average one part of phosphoric anhydride from the pig iron yields 7·36 parts in the slag; some of the German works obtain as much as 9·3 parts.

Slag-Grinding Mill.—All the basic Bessemer slag made at the Rothe Erde Works, Germany, is cast into tank waggons, and is then taken to the grinding mill. The slag as it reaches the mill is still partly liquid, and this is poured on to iron plates to facilitate the breaking

* *The Engineering and Mining Journal*, vol. xlvii. pp. 522, 569.

† *Transactions of the American Institute of Mining Engineers*, vol. xvii. pp. 84–94.

It was afterwards found that this grade of iron could be readily produced.

After an historical introduction, the author proceeds to discuss the use of the various elements present in silicon-iron, and gives the following analysis as representing the composition of No. 1 Bellefonte Foundry Iron :—

Combined Carbon.	Graphite.	Silicon.	Phosphorus.	Sulphur.	Manganese.
0·30	3·18	2·60	0·35	0·03	0·50

Combined carbon increases the hardness and brittleness of cast iron. Such metal shrinks more in cooling than does metal containing the carbon in the graphitic form. The presence of sulphur or manganese promotes the formation of combined carbon. Graphitic carbon, on the other hand, renders cast iron soft and tough. Silicon tends to cause the conversion of combined carbon into graphitic carbon, it increases the fluidity of cast iron, prevents shrinkage, and renders the metal difficult to chill. Sulphur hardens iron. It is powerful in its action, which is the inverse of that of silicon, 1 part of sulphur neutralising the effect of 5 or 10 parts of silicon. In soft foundry irons the percentage of sulphur should not exceed 0·13, for hard and mottled irons 0·20, nor for white irons 0·25. The presence of phosphorus induces hardness and brittleness; it increases the fluidity. Manganese renders the iron brittle. It causes the conversion of graphitic into combined carbon. It makes iron fluid, reduces shrinkage, and tends to produce clean castings.

Tests of Foundry Mixtures.—Messrs. Rodgers, Brown & Co., of Cincinnati, have published * the results of a series of tests of various foundry mixtures. The number of mixtures tested was 119, the test-pieces broken numbering about 300. These latter were 1 inch square and 24 inches in length between the supports. It was observed that nearly all the bars overran in size from $\frac{1}{32}$ to $\frac{1}{8}$ inch. The test-pieces were made chiefly at foundries in Ohio, Indiana, and Missouri, the mixtures being from coke and charcoal irons, the foundries using charcoal iron forming about 20 per cent. of the total number. The average strength of the test-pieces was 1120 lbs., 37 breaking below 1000 lbs., whilst 12 broke at above 1400 lbs., and 3 at more than 1500 lbs. One bar, in which wrought iron scrap and ferro-aluminium were mixed with pig iron, broke at 1958 lbs. This was the strongest bar examined, but it was difficult to drill or work. The next strongest bar was from a

* *Iron Age*, vol. xliii. p. 542.

and this again is dependent on the presence or absence of too much combined carbon. When but little phosphorus is present the percentage of combined carbon may reach 1·5, without rendering the casting brittle, but where much phosphorus is present, as is usually the case, the combined carbon should not exceed a few tenths per cent. On the other hand the percentage of combined carbon must not be too low and the phosphorus too high if castings of considerable strength are to be produced, for the strength, hardness, and specific gravity of the metal increase with the percentage of combined carbon. When the iron contains 0·25 per cent. of phosphorus, the greatest strength will be obtained with 0·8 to 1·4 per cent. of combined carbon, and it is absolutely certain that as the percentage of phosphorus increases, that of the combined carbon should become lower. It seems as though by a partial replacement of the combined carbon by silicon and phosphorus the strength of the metal is increased. Silicon, like combined carbon, though in a less degree, increases the strength of cast iron; but its action is less a direct one than by its influence on the state of the carbon. The direct action of silicon is indeed very different, as it not only does not diminish the brittleness of the iron but actually increases it, and increases the hardness. With regard to the influence of manganese, this element, like sulphur, but in a much less degree, causes the formation of combined carbon. Ordinary foundry iron may contain about half as much manganese as there is silicon present, without seriously affecting the action of the silicon, and it is even probable that a percentage of manganese such as this acts beneficially. For very strong iron a larger percentage of combined carbon is necessary than that present in ordinary foundry iron, and consequently the relative percentage of silicon must be diminished and that of manganese increased. The influence of phosphorus on the state of the carbon is also similar to that of sulphur, but its action is even less energetic than that of manganese. Like sulphur and manganese, it influences not only the condition of the carbon, but also diminishes the total percentage which the iron can take up. If a strong casting is required, the percentage of phosphorus may be as much as 1·5 without inducing brittleness, provided a sufficient quantity of silicon is present to keep the combined carbon down to a few tenths per cent. Phosphorus has the advantage of increasing the fluidity of the metal, and its presence even in considerable quantities may thus prove beneficial.

The author refers to the change in the character of pig iron produced by remelting, the loss of silicon this involves, and the change in state

steely iron with 5 per cent. of carbon with inclusions of graphitic seggregations. On analysis the iron yielded :—

Si.	Combined C.	Graphite.	Mn.	P.	S.
2·22	0·49	2·24	0·45	0·93	0·30

A cube of this iron, 1·18-inch side, broke after eleven blows, with an expenditure of 870 foot-lbs. of work.

A pump cylinder, 19·29 inches in diameter, 6·29 inches in thickness, and 2·1 tons in weight, was found to be thoroughly sound under a pressure of 280 atmospheres. The author is consequently of opinion that the manufacture of large machine parts by melting white pig iron with ferro-silicon is the only correct method.

The author further refers to the use of silicon in general for foundry purposes, and also to the possible extended use of aluminium for similar purposes.

Cupolas.—The success of the Herbertz cupola * has been so great that in three years in Germany alone 150 of these cupolas have been erected. During the three years the cupola has, according to Sahler,† passed through all phases of development. The chief advantage of this cupola consists in the production of a dense and soft cast iron, even from poor brands. This is due to the fact that through the uniform aperture for the admission of air passing around the body of the furnace, the exterior atmospheric air enters into the furnace at quite a low tension, effects the combustion of the coke, close above the aperture, with formation of carbonic anhydride, and thus melts the iron with as small as possible a withdrawal of carbon and silicon. The iron is not, as in other cupolas, rendered viscous in the upper portions of the furnace, but passes well-heated into the fusion zone. The consumption of coal in the production of the steam has been determined at the works of Sulzer Brothers. It is found to require 1·80 lb. for heating the boiler in order to melt 100 lbs. of iron. A cupola of this type at the Isselburg Works melts 4 to 5 tons of iron per hour. In trials recently made with heated air, the air was heated to 400° C. by means of the furnace itself, and it was found possible to melt steel and even wrought iron.

Baron von Manteuffel reports that, of the more recently invented cupolas, those of Herbertz and of Greiner and Erpf consume least material. At the Lauchhammer ironworks, a Herbertz cupola is in

* *Journal of the Iron and Steel Institute*, 1887, No. II. p. 296.

† *Dingler's polytechnisches Journal*, vol. cclxxiv. pp. 163–170.

section, uniform from end to end, should be used, and then the bar may be square or oblong in section indifferently.

By this method, therefore, after breaking any plain rectangular bar of uniform section, multiply half the breaking load in pounds by the deflection in inches, and divide the product by the weight of the bar in pounds. The result varies from 10 for the worst irons to 75 for the best. A result of 25 corresponds to the grade used for gas and water pipes, 40 to 50 to the better grades of machine castings, and stove irons give a result of 50 to 70.

The author has designed a simple apparatus which uses an ordinary platform scales for making the required tests. The bar is supported at its ends on knife-edges carried by tripods. One tripod is placed on the platform of a weighing machine registering up to 2000 lbs. The load is applied at the centre of the bar by a hand wheel and screw, which works in a standard on the trolley carrying the apparatus. Uprights spring from each tripod, and carry a horizontal reference bar with micrometer screw in the centre. The micrometer is adjusted to measure the distance through which the power screw moves downwards to the nearest thousandth of an inch, that is, to measure the deflection, and half the breaking strain is read directly from the lever of the weighing machine, provided the breaking strain is put on the centre of the bar.

Iron Manufacture in Central Africa.—According to Mr. F. S. Arnot,* the iron trade caste in the Garenganze tribe are very expert in working iron. The ore is smelted in open trenches filled with iron ore and charcoal, and covered with soft mud. Openings are left at both ends; the fire is lit at one end and blast produced by bellows. The iron is manufactured into hoes, axeheads, spears, knives, chains, and bullets.

* *Iron and Steel Trades Journal*, vol. xxxix. p. 240.

Experiments with a steam-hammer on lead ingots weighing 3 lbs. and containing 30·73 cubic inches, gave :—

No. of Blows.	Length in Inches.	Mean Diameter in Inches.	Stroke of Hammer in Inches.	Inch Pounds Developed.	Pressure per Square Inch. Lbs.
1	2	3·64	19	156,180	20,553
2	1⅜	4·38	19⅝	161,317	20,792
3	1½	5·22	20 1/16	164,660	20,792
4	¾	5·93	20¼	166,455	31,501
5	⅝	6·50	20⅝	167,482	44,362

Compression of similar billet in a wheel press to show the action of hydraulic pressure in making the same deformation as each hammer blow had produced :—

Length in Inches.	Sectional Area.	Gauge Pressure in Pounds per Square Inch.	Total Pressure in Pounds.	Mean Diameter in Inches.	Pressure per Square Inch. Lbs.
2	10·8	1000	63,617	3·71	5890
1⅜	15·71	1600	101,787	4·47	6415
1	21·6	2500	150,042	5·25	7383
¾	28·8	4100	260,330	6·06	8056
⅝	34·56	5000	318,085	6·63	9200

The frictional resistances to extension become greater in the latter case, but at no time is the pressure greater than one-third the calculated result of the hammer blows. A similar result was found with hot steel and iron in a mould; 6000 lbs. pressure was required to cause the metal to fill the mould, and 16,000 lbs. to insure the sharp corners being quite filled.

The forging machine can work as rapidly as the hammer. Rapid compression at one stroke may be permitted in compressing ingots for tire making, an effect impossible to attain with the hammer. The power press is self-contained, and will not be broken with sudden shocks, whilst even small hammers must be separate from the anvils.

Forging Drop Press.—A new drop power forging press has been constructed by the E. W. Bliss Company, of Brooklyn. The principal feature of the machine is the peculiar shape of the hammer, which is essentially a steel billet placed on end and hammered out at the bottom to give proper support to the die. This construction concentrates the

Pneumatic Moulding Machine.—A new pneumatic method of moulding has been described by Mr. G. Richards.* In the first moulding machines the sand was rammed or pressed by a flat plate, and next the pattern was mechanically withdrawn after the mould was made. Subsequently these methods were combined, and machines were made with flat pressers and withdrawable moulds. The chief difficulty in these machines is to ram the sand uniformly, and experiments were made with divided presser plates, and afterwards india-rubber bags, into which air could be admitted, were tried. These succeeded admirably, and the machine was speedily developed into one with a rotary head. The machine has two heads swivelling on one of the pillars of the machine; the pattern is raised and lowered by levers which can be locked in position. While one head is being rammed up, the box on the other is brought under the sand hopper. The pressing head contains the required number of pressing bags, to which air is admitted at 50 lbs. pressure. In working the machines, five men each are employed, and forty to fifty boxes per hour of excentric clips, 8 to 12 inches diameter and 2 inches deep, were produced in one trial, and other trials were also given. The total cost of a 16-inch machine, sand conveying apparatus, and boxes, is stated to be £350, and the cost of production 3 pence per box.

* Paper read before the Manchester Association of Engineers, October 26.

important feature being that the whole of the train and tables is commanded by a 10-ton overhead travelling crane.

In 1888 the Rothe Erde Works produced 141,486 tons of basic ingots, and 11,746 tons of puddled blooms. The rolling mill turned out 152,254 metric tons of merchantable goods, and 1150 tons of drawn wire and wire nails. The pig iron consumed amounted to 185,913 tons, the consumption of coal being 98,529 tons, of coke 19,205 tons, of lime 26,519 tons, and of limestone 3882 tons. About 2300 work-people were employed; the sum paid as wages was £110,533.*

* *Iron Age*, vol. xliv. p. 120.

wires, and the angle of twist of each layer is different from that of any other layer.

It is evident that the welding of a cable of this form is a matter of some difficulty. The following conditions had to be met:—1. It was necessary to provide means for preventing the separate wires from fraying outwards when the longitudinal pressure used in the welding was applied. 2. It was necessary that the cable should be gripped in such a manner as to prevent sliding movements of the wires with relation to each other. 3. An unusual preparation of the ends had to be made in order to accomplish, at least approximately, the separate welding of the wires composing the cable, so that in bending around a sheave the load strains might be distributed at this point in the same manner as at any other point. 4. It was necessary to have the ends of the wires at one terminal as nearly as possible in line with the ends of those in the other terminal. In order to prevent the fraying and expanding actions above mentioned, it is found necessary to shrink mild steel or iron sleeves or collars tightly upon the cable close to the ends (about $\frac{1}{16}$ inch therefrom), and this arrangement is found effective in preventing the wires from sliding over each other when the pressure is applied in welding; but it also prevents the separate welding of the wires forming the cable, a difficulty overcome by special preparation of the ends of the cable—by cutting grooves between the ends of the contiguous layers of wires, forming thereby a series of concentric circular grooves. This permits of a definite amount of "upset" of softened metal at the end of each wire, which must be allowed for, it being caused by the endwise pressure used in forcing the pieces together when the welding temperature is reached, and permitting also the welding together of the wires forming the cable. The ends of the separate wires can be brought exactly opposite each other by the exercise of ordinary care upon the part of the operator of the machine.

Experiments made with a view to determine the tensile strength of the welds produced, showed that the maximum tensile strength of the cable was 67,000 lbs. per square inch before annealing, and about 50,500 lbs. after heating to a temperature slightly below a welding heat, and then allowing the metal to cool slowly. The tensile strength of the welded cable averaged over 50,000 lbs., some specimens resisting a stress of as much as 53,000 or 54,000 lbs. per square inch. The ratio of elastic limit to ultimate tensile strength is about the same in unwelded as in welded specimens. Severe bending and twisting

but little power is here lost, the wear is exceedingly small, and the remarkable rapidity above-mentioned is made possible.*

Universal Milling Machine.—The *Iron Age* † publishes detailed illustrations of a universal and automatic milling machine, designed by L. H. Nash. It was specially intended for the purpose of cutting the gears and pinions used in a water-meter, a work in which considerable accuracy was necessary. The machine described has cut over 100,000 gears a year for over seven years, and the repairs have been but slight.

A number of universal milling machine attachments are also described and illustrated.‡

Pipe Cutting and Threading Machine.—A new machine of this class, manufactured at Bridgeport, Connecticut, is arranged to cut off and thread all sizes of wrought iron pipe, from 2½ to 12 inches in diameter. The die-carrying gear is supported in a casing with the pinion embedded in its side. On the back of the gear is placed a lead screw of the same number of threads to the inch as the pipe to be cut, which engages with the brass lead blocks on the sides of the shell, and which work out or in by eccentrics. Thus as the gear revolves in the shell it is drawn into it by the lead screw, and the dies are brought on to the pipe. The description is accompanied by an illustration showing the general arrangement of the machine.§

A similar machine, manufactured at St. Louis, Montana, is so arranged that the dies throw open far enough to allow the pipe to pass through to the cutting-off tool without opening the die head or sliding it on one side. The machine is supplied with the Peerless die head, reversed so as to place the dies next to the gripping chuck. This latter is of great strength, and has three independent jaws which are graduated to the different sizes of pipe.||

Riveting Machines.—Two forms of riveting machines are illustrated in the *Iron Age.*¶ They are of American construction. One is an elastic rotary blow machine in which the hammer rod, suspended by springs and confined air within the cylinder, partakes of its reciprocating motion, and produces a sharp, quick blow. Both hands of the

* *Iron Age*, vol. xlix. p. 242, with detailed drawings.

† Vol. xliii. p. 501, 3 illustrations.

‡ *Iron Age*, vol. xliii. p. 428, 6 illustrations.

§ *Ibid.*, vol. xliii. p. 951.

|| *Ibid.*, vol. xliv. p. 48, 1 illustration.

¶ Vol. xliii. p. 313.

Nails from Tin Scrap.—Nails made by pressure from tin scrap were first invented by Mr. G. H. Parker, and Mr. O. Smith,* who has been associated with him, describes the development of the manufacture. In the first attempt, approximately rectangular blanks were corrugated, and then the corrugations crushed together, the heading being performed in a separate machine. One machine was then devised to perform all these operations automatically, but it was found that there was a tendency to split in the tightly folded corrugations. It was then found better to crush up the blanks edgewise into any form they chose to assume, and in the latest machine irregular scrap can be fed by the operator, and the finished nails automatically delivered at the rate of thirty to ninety nails per minute. It was also attempted to coil the blank, but this is too expensive. The best form has a square taper shank, similar to a cut nail. The nails do not rust much, and will take solder.

Horse-Shoe Nail Iron.—H. Wedding † shows that the ingot iron from the Peine Works is as well adapted for the manufacture of horse-shoe nails as is Swedish charcoal iron.

Rail Sections.—The ability of a rail to resist all strains to which it is subjected, depends quite as much on the character of the metal as on the form of the section. Consequently, in designing the section, ample allowance must be made for the varying qualities of the material. Mr. R. W. Hunt ‡ returns to this subject, and again points out the pernicious effect of rolling at high temperatures. Earlier rails certainly did not owe their excellent wearing capabilities to their composition, as the carbon varied from 0·24 to 0·70 per cent., silicon from 0·032 to 0·306, phosphorus from 0·077 to 0·156, and sulphur from 0·050 to 0·181 per cent. in some that the author examined.

The great increase in the load on the wheel flanges calls for a broader head on the rail, and a heavier section generally, but, at the same time, the railroad engineer tries to secure this with the smallest outlay. The New York Central and Hudson River Railroad are relaying the whole Hudson River section with the Dudley rail of 80 lbs. per yard. The author's proposed sections have, however, departed from this design and approximate to that in use on the

* *Transactions of the American Institute of Mining Engineers*, vol. xvii. pp. 495–498.

† *Verhandlungen des Vereins zur Beförderung des Gewerbefleisses*, 1889, p. 90.

‡ *Transactions of the American Institute of Mining Engineers*, vol. xvii. pp. 778–785.

	Chemical Composition.					Tensile Strength.	Elastic Limit.	Elongation per Cent.	
	C.	Mn.	Si.	S.	P.	Tons per Sq. Inch.	Tons per Sq. Inch.	On 7·87 Inches.	On 3·94 Inches.
Sheets and angles	0·183	0·480	0·020	0·034	0·055	25·4–28·6	14·6–17·1	23–33	27–40
Bearing parts, Cast	0·350	0·600	0·250	0·430	0·075	28·6–34·9	...	9–24	–
Bearing parts, Forged						38·7–45·7		10–22	

Malleable Iron and Steel Eye-Bars.—Mr. C. Gayler, in a paper recently read before the St. Louis Engineers, United States, pointed out that steel is very rapidly replacing iron in the manufacture of eye-bars. Very small percentages of phosphorus, however, appear to render steel useless for the purpose, and bridge companies have found it necessary to limit the possible percentage to 0·04; the percentage of carbon should be from 0·1 to 0·2. The steel used for eye-bars in the construction of the Grand Avenue Viaduct, St. Louis, is Bessemer metal containing from 0·13 to 0·16 per cent. of carbon, and from 0·03 to 0·06 per cent. of phosphorus. The tensile strength of this metal was from 62,000 to 70,000 lbs. per square inch, with an elastic limit of 32,000 lbs. The minimum elongation was 18 per cent., and the ¾-inch bar had to bend 180° around its own diameter without cracking. In the manufacture of the eyes, the excess of material across the eye over the bar was 40 per cent.

Chain Cable.—M. Meurgey * has published a report by M. de Saint-Hilaire on a new form of chain cable invented by M. Delage. The cable consists of a number of wire helices threaded into each other corkscrew fashion with a screw bolt passed between each pair of helices at their intersection. The bolt heads and nuts lie alternately on opposite sides of the cable, and the ends of the helices are secured to the bolts. Each helix is somewhat flattened to give an oval section, and each turn in the helix bears on the bolt at both ends and takes up its share of the strain.

A chain with seventeen turns in each helix, made of wire Nos. 20, 21, or 22 (French), has a thickness of 9·84 inches, with 52 helices to the yard. Taking the tensile strength of the wire as 38 tons per square inch, chains made of the above sections of wire will support 55,000, 70.000, and 88,000 lbs. respectively. Some results of tests given

* *Rendus Mensuels de la Société de l'Industrie Minérale*, 1889, pp. 70–79.

later by M. Buisson * show, however, that the breaking strain is only 48,280, 59,083, and 66,799 lbs. respectively, a result much inferior weight for weight to that of wire and other ropes.

The report then deals with the adaptability of this form of chain for coal-mining purposes. Ropes of vegetable fibres are stiff and heavy, wire ropes are also very stiff. Chains will wind round a small drum, but are clumsy, likely to break in a badly welded link, and liable to crystallisation. The form of chain under consideration, however, will bend as easily as an ordinary chain, and at the same time each link is composed of several turns, so that it can yield somewhat, and one turn may even be broken without the whole link giving way. Besides this the chain is not liable to crystallisation, may easily be examined, and may be made of any quality of wire.

The weight of the chain is its most serious objection, but this might be reduced by flattening the helices still more, by using hollow bolts, and by using a thinner wire.

* *Comptes Rendus Mensuels de la Société de l'Industrie Minérale*, 1889, p. 92.

PHYSICAL PROPERTIES.

Hysteresis in the Relation of Strain to Stress.—When iron wire is subjected to the alternate application and removal of stress certain of its qualities exhibit hysteresis or lagging in responding to the charge of stress. This lag varies from point to point in a cycle, as is shown by Prof. J. A. Ewing.* Similar changes have been shown to exist in the magnetic and thermo-electric properties. Experiments were made by loading and unloading a long wire, and observing the facility with which the elongation followed the load. In the most successful form of apparatus a long wire was suspended in a flue to keep it as nearly as possible at a constant temperature. Two other wires were suspended near by to form a fulcrum for a mirror attached to the first wire in order to remove as far as possible all effects of temperature. Readings could be taken to show an extension of 0·000,000,102 of the length of the wire.

The wire was kept stretched by a constant weight, and a load of 20 kilogrammes was put on and taken off several times at varying rates. When the operation was performed as quickly as possible the difference of extension between the point at which 10 kilogrammes had been put on, and the point at which 10 kilogrammes had been taken off, amounted to 0·00,000,357 of the length of the wire, equal to a difference of 66 grammes in the load. The hysteresis appeared to be permanent under some conditions, as an interval of two hours did not affect it, but it varied according to the rate of loading. The trial mentioned above was made with hard drawn iron wire, 1·08 millimetre diameter; other experiments were made with mild and hard steel wires.

The experiments show that under certain conditions there is a departure from Hooke's law, one effect of which is that work is done on the material when it is put through a cycle of stress change. The results obviously bear on the conclusions of Wöhler with regard to the deteriorating effect of repeated variations of stress.

* Paper read before the British Association Newcastle meeting).

phosphorus, 0·08. A test piece, 2 inches long, 0·564 inch in diameter, and 0·25 square inch area, planed out of a tire so composed, showed on an average a maximum tensile strength of 37 tons per square inch, an elongation of 26 per cent., and a reduction of area of 47 per cent., the fracture being grey and granular with silky edges, and the shape convex and concave. A tire of this material, with an inside diameter of 2 feet 8 inches, and a sectional area of 11 inches, showed a deflection of 6½ inches under a weight of 22 cwt., falling 12 feet, and while it was perfectly adapted to fulfil all requirements, it was proved to be little liable to molecular change under sudden, heavy, and repeated shocks. While an increased proportion of carbon would increase the tensile strength, it would render the tire liable to break under the falling weight test. The only means, therefore, of increasing the tensile strength, and at the same time preserving the normal deflection, was to increase the manganese. Similar tests of a steel practically identical in composition with that given above, but with the addition of 0·5 per cent. of manganese, showed that the tensile strength was raised from 37 to 42 tons per square inch; the elongation reduced from 26 to 18 per cent., and the reduction of area decreased from 48 to 26 per cent., while it required 15½ foot-tons additional to produce equal deflection. But a tensile strength of 48 tons, an elongation of 15 per cent., and a deflection of 2 inches to the foot, has been specified, and to obtain this by adding manganese would require 2·5 per cent. of that element. No steel-maker would risk the inevitable brittleness of such a metallurgical deformity. Hence, chromium is resorted to, and this, added in small quantities, raises the tensile strength in a remarkable degree without seriously diminishing ductility, but when added in too high a proportion it induces brittleness. The results of tests made of tire-steel containing 0·42 per cent. of chromium, and 1·54 per cent. of manganese, showed a tensile strength of 49·8 tons per square inch, 15 per cent. elongation, and 26 per cent. reduction of area, the fracture being flat and finely crystalline, and the falling weight showing a deflection of nearly 12 inches at a 20-feet fall. But tests of the broken tire showed that the tensile strength was 47·7 tons per square inch, the elongation 3 per cent., and the reduction of area 6·4 per cent., the fracture exhibiting large crystals. The molecular change set up by the shock and vibration of the falling weight was thus most clearly indicated; and, although it was possible to get a tensile strength of 50 tons per square inch, together with great strength under the drop test, such tires were very uncertain. Further tests showed that the effect of annealing was not

The elongation of the unhardened bar was 2·2 per cent., and of the hardened bar 10·0 per cent. Calculated on the final reduced area, the tensile strength of the hardened bar was 62·28 tons.

Test cylinders each approximately 0·39 inch in height, and the same in diameter, were then weighted with a load of 32 tons. After having been submitted to this stress, it was found that the unhardened cylinder was reduced in height from 0·39 inch to 0·20 inch, and that of a cylinder hardened in oil from 0·38 inch to 0·23 inch; a similar cylinder which had been hardened in water was reduced in height from 0·41 inch to 0·38 inch.

Tensile Tests of Hungarian Basic Steel.—A. Gouvy* gives the following results of tests of basic open-hearth steel made at the Resicza Steel Works, Hungary:—

No.	Percentage Composition.				Tensile Strength.	Elongation.	Reduction of Area.
	C.	Si.	P.	Mn.	Tons per Square Inch.	Per cent.	Per cent.
1	0·220	0·025	0·014	0·350	22·03	32	72·0
2	0·177	0·012	0·014	0·115	21·78	29	68·4
3	0·232	0·023	0·011	0·022	22·98	25	70·8
4	0·191	0·035	0·011	0·151	20·00	28	75·5

The results of a number of other tests are also given.

Drifting Tests.—Mr. A. C. Cunningham † gives the results of a number of drift tests of steel. In one case a plate was examined which contained 0·073 per cent. of phosphorus, and had a tensile strength of 65,000 lbs. per square inch. The original punched hole was of $\frac{7}{16}$-inch diameter, and the centre of the hole was 1 inch from the rolled edge and 4 inches from the sheared end. After drifting to $1\frac{1}{2}$-inch diameter, an increase of 245 per cent., a hole of the same size as the original one was punched at the side of the drifted hole. Two other tests made with a plate containing 0·006 per cent. of phosphorus, and having a tensile strength of 46,000 lbs. to the square inch, showed still more favourable results.

Successful drifts, the author states, become the more difficult to

* *Stahl und Eisen*, vol. ix. p. 401.

† *The Engineering News*, through *Iron Age*, vol. xliv. p. 43.

Steel for Gun-Barrels.—Mr. R. W. Hunt * observes that steel for gun-barrels must be low in manganese, as when much is present the steel throws a long chip before the drilling tool. A very satisfactory metal had the following composition:—

Carbon.	Silicon.	Phosphorus.	Sulphur.	Manganese.
0·290	0·212	0·048	0·065	0·370

Manganese is further deleterious in that it strongly affects the hardening properties of steel, giving rise to the formation of water-cracks.

An Automatic Testing Machine.—The *Iron Age* † illustrates the latest form of testing machine constructed by Messrs. Tinius Olsen, of Philadelphia. One end of the test piece is attached to the upper plate of the machine and the other end to the lower plate. The lower plate or cross-head is secured to four straining-screws which pass through holes at the carriers of the weighing platform of the machine, through openings in the levers and bed-plate, and enter the driving-nuts situated below the latter. Feathers fitting into longitudinal slots cut through the threads of the screws prevent them from turning, and they therefore either rise or fall and carry the lower plate with them as the nuts are rotated. These nuts are operated through bevel gearing by outside spur gearing and a counter-shaft. The counter-shaft is provided with double cone and friction pulleys, admitting of six downward or pulling speeds and two upward speeds.

For tensile tests the ends of the specimen are secured to the plates by steel wedges which enter rectangular openings cut through the centres of the plates. Interposed in the space between the wedges proper and the plate are spherical surface bearings by which the wedges are adjusted to the specimen, and the specimen is adjusted centrally and on a parallel line to the line of greatest stress, and a straight pull secured.

The weighing apparatus consists of the main levers upon which the platform rests, three in number, so constructed as to act as a single lever, and supporting the platform upon which rest the columns which carry the upper plate or cross-head. As one end of the specimen is secured in the upper cross-head any stress imparted to the specimen by the lower straining-head will be communicated through the columns and platform to the levers. The stress on the main lever is through an intermediate lever connected to the beam, where the amount is balanced and thus registered. The stresses are automatically balanced on the beam, this being accomplished by a coarse-thread screw placed on the top of the beam, the sliding weight being moved by this screw. At

* *Journal of the Franklin Institute*, vol. cxxvii. p. 375.

† Vol. xliii. p. 956, 2 illustrations.

CHEMICAL PROPERTIES.

Effect of Manganese on Chill.—Some recent experiments * have been made on the effect of manganese on chill. Starting with 1 lb. of manganese to the ladle capable of pouring a 550-lb. wheel, the addition was increased at ½ lb. a time. Up to 7½ lbs. there was no appreciable effect, but from this point up to 10 lbs. the depth of chill increased from a trifle over half an inch to three-quarters of an inch. The principal peculiarity noticed throughout was the fibrous extensions of the chill down into the grey iron, whereas the inner edge was straight when no manganese was used.

The Rusting of Rails in Tunnels.—Mr. Thörner † has analysed a large number of samples of rust taken from the surfaces of rails laid in tunnels. The author finds that sulphuric acid is always present in considerable quantities, and he shows that the gases escaping from locomotives, besides containing sulphurous anhydride, contain unexpectedly large quantities of sulphuric acid, and that it is to this cause that the undue rate of oxidation of ironwork in railway tunnels is due. The author further finds that those parts of the ironwork which are kept wet by dropping water are less oxidised than other parts which are not subject to this action.

Bessemer Steel.—In an address delivered before the Franklin Institute, Philadelphia, Mr. R. W. Hunt gave the following results of analyses of various articles made of Bessemer steel:—

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* *National Locomotive and Car Builder*, through *American Manufacturer*, vol. xlv. No. 7.

† *Stahl und Eisen*, vol. ix. pp. 821-836.

Steel for	Carbon.	Silicon.	Phosphorus.	Manganese.
1. Planters' hoes	0·76	0·185	0·059	0·441
2. Scarf steel	0·52	0·150	0·068	0·406
3. Circles and plungers for rifles .	0·66	0·171	0·057	0·416
4. Machine screws . . .	0·46	0·223	...	0·316
5. Hoes	0·61	0·158	0·086	0·445
6. Pitchforks and large forks .	0·63	0·241	0·073	0·610
7. Planters' hoes	0·52	0·150	0·043	0·376
8. Gooseneck hoes . . .	0·53	0·249	0·040	0·413
9. Spring steel, Jenks' English .	0·64	0·145	0·088	...
10. Spring steel, Jenks' English .	0·52	0·150	0·060	0·030
11. Spring steel, Graves' Swedish .	0·53	0.110	0·030	...
12. Spring steel, Graves' Swedish .	0·76	0·840	0·018	0·085
13. Spring steel	0·65	0·185	0·102	...
14. Hatchets	0·70	0·270	0·041	0·195
15. Swords	0·64	0·258	0·017	0·453
16. Scythes (German steel) . .	0·63	0·127	0·056	0·212
17. Cutlery, knife	0·51	0·180	0·029	0·265
18. Fork	0·49	0·335	0·030	0·444
19. Cutlery	0·61	0·210	0·046	0·402
20. Tool	0·88	0·220	0·023	0·140
21. Tool	0·85	0·204	0·022	trace
22. Tool	0·85	0·190	0·022	0·174
23. Tool	0·86	0·216	0·030	0·001

No. 1 and 2, Lane, Gale & Co.; 3. Providence Tool Company; 4. Hartford Machine Company; 5 and 6. Huntly & Babcock, Utica, New York; 7 and 8. Remington; 13. Naylor's, Bridgeport, Connecticut; 14. Johnsville Axle Works; 15. Ames & Co.; 16. Stock used by A. S. Millard; 17 and 18. Landers, Frary & Clark, New Britain, Connecticut; 19, 20, 21, and 23 made by Park Brothers; 22. Frith's English.

Thermo-Chemistry.—In discussing the paper read by Mr. A. Pourcel before the Iron and Steel Institute, Professor Ledebur * points out the great importance of the question of thermo-chemistry. Before, however, any accurate calculation can be made, it will be necessary to determine definitely in what state of combination the various substances exist which occur in a bath of molten iron, and what are the real products of the combustion of such impurities. Now, neither the one nor the other of these points is in any way settled. Further, the influence of mass and temperature in determining the reactions must not be overlooked.

* *Stahl und Eisen*, vol. ix. pp. 712-717.

CHEMICAL ANALYSIS.

CONTENTS.

I.—*ANALYSIS OF IRON AND STEEL.*

Sampling of Materials Used and Produced in the Manufacture of Iron and Steel.—The proper sampling of materials is a matter of great importance, for on it depends the value of an ore, of a mining property, the correctness of the charges for the blast furnace, and much else besides. Some rules for proper sampling are given by Mr. G. L. Luetcher.*

Ore.—The sample of ore from cargoes, trucks, or mines should represent both the dry and the wet condition with all impurities. Moisture can best be determined from a sample taken from holes in the ore 2 feet deep, or after it is tipped in the case of mined ore. Everything should be taken as it comes, and about 200 lbs. dried in a shallow iron box over the boilers for about ten hours. Up to a ton may be taken if the ore can be worked up in a grinding pan, and of this about 200 lbs. should be taken as representative.

Ore in Mines.—Each heading should be sampled and analysed separately, or else a proper proportion should be taken from each heading or working place. A heading may be sampled by dividing the face into square feet and taking an equal amount from the centre of each square. If the vein or seam lies in uniform strips, then a transverse section should be taken. Ores of different character should be sampled separately. In sampling the "run of the mine," equal quantities of coarse and fine should be taken from each car.

* *American Manufacturer*, vol. xlv. No. 8.

There seems to be no evidence of the formation of any precipitate of ammonium silico-molybdate. If the separation of silica is omitted, much time is saved by using the process adopted in the laboratory of the Massachusetts Institute of Technology. About 1·5 gramme of pig iron is dissolved in 60 cubic centimetres of nitric acid of 1·135 specific gravity by heating on an iron plate. The solution is effected in about three minutes, and is filtered from the graphite; to the boiling filtrate there is added 15 cubic centimetres of permanganate solution containing 5 grammes of salt to the litre. Boiling is continued till the pink colour has disappeared, and a small quantity of tartaric acid is added to dissolve the manganese oxide. As much as 1 gramme of tartaric acid will not affect the result, but about 0·1 gramme only is required. To the solution 10 cubic centimetres of strong ammonia is added, and it is then cooled to about 90° C. before the addition of 80 cubic centimetres of molybdate solution. From this point the method of reduction by zinc and titration by permanganate is followed.

By the old method, a sample of pig iron containing 2·42 per cent. of silicon gave 0·284 per cent. of phosphorus, and by the new method it gave from 0·272 to 0·294, or by averaging twenty-two experiments 0·285 per cent. In order to attain still greater rapidity the graphite need not be filtered off. Determinations in this manner gave the following results:—

	Silicon.	Phosphorus.	
		By the Old Method.	By the New Method without Filtering from Graphite.
	Per cent.	Per cent.	Per cent.
Grey forge iron . .	0·63	0·632–0·635	0·620–0·645
Bessemer iron . .	1·18	0·084–0·087	0·083–0·086
Foundry pig iron . .	2·29	0·334–0·330	0·322–0·334
Bessemer steel . .	...	0·061	0·060–0·064

Determination of Silicon.—For determining silicon in steel, Mr. C. Jones * uses Dr. B. Drown's method with rapid evaporation. The solution is placed in a platinum dish heated by two flames, one below, and the other directed on to the surface of the liquid. It is found that 50 cubic centimetres of nitro-sulphuric acid is evaporated in three minutes, and the salts are left as a thick pasty mass which can be at once

* *Journal of Analytical Chemistry*, vol. iii. p. 121.

STATISTICS.

CONTENTS.

I.—*UNITED KINGDOM.*

Iron Ore.—The production of stratified ironstone from coal mines in the United Kingdom during 1888 amounted, according to the official statistics,* to 8,635,032 tons, valued at £1,838,844. The amount of metal obtainable from this ore is 2,590,510 tons. The amount of iron ore raised was 2,937,253 tons, valued at £1,317,021. The amount of iron ore obtained from open works was 3,018,428 tons, valued at £345,452. The total production of all classes of iron ore was therefore 14,590,713 tons, valued at £3,501,317.

Pig Iron.—The number of ironworks in operation in 1888 amounted to 150. There were 836 blast furnaces, of which number 424 were in blast. The amount of pig iron made was 7,998,969 tons, and in its manufacture there was used 19,152,074 tons of iron ore, and 16,131,267 tons of coal.

Iron Trade Statistics.—According to the returns made to the British Iron Trade Association, the production of pig iron in the United Kingdom during the first half of 1889 amounted to 4,083,597 tons, being an increase in make of 87,767 tons as compared with the

* "Mineral Statistics of the United Kingdom for the Year 1888. Prepared by Her Majesty's Inspectors of Mines." London, 1889.

in 1888 the output reached 170,000,000 tons. There seems reason for believing that the output had been doubled during each quarter of a century. In 1860 the author calculated that there was sufficient coal, not deeper than 4000 feet, to last for 1000 years at the then rate of production. Since then the reserves have been reduced by 3,650,000,000 tons, an amount which, though great, has not materially affected our coal resources. The production of the South Wales coalfield had doubled between 1854 and 1879, and amounted to 27,355,000 tons in 1888, largely owing to the demand for steam coal in the Cardiff district. The resources of this basin are enormous, and the Lancashire, Cheshire, Yorkshire, and Nottingham coalfields are highly progressive, as are also the Northumberland and Durham fields. The great northern field, notwithstanding the long period during which it has been worked, shows no signs of falling off.

The discovery of ironstone in the Cleveland district, and the great exports from the northern ports, have given a vast impetus and caused an enormous drain, but there is sufficient coal left in the district to produce at the present rate for three centuries. The relation of the iron deposits in the North Riding, in North Lancashire and Cumberland, was then considered in relation to the coal production, and the different coalfields were passed in review to show which were progressive, and which were stationary or retrogressive. Finally, the author was of opinion that the enormous output has not seriously crippled our resources, but that there is likely to be a general rise in the value of coal in the near future, owing to the greater depth and increased cost of mining. Reference was made to coal mining in America, and the author agreed with Prof. Jevons that we cannot expect an importation of coal from the United States when our own becomes scarce. In the discussion which followed the paper, Mr. S. Bourne pointed out our large export of some 20,000,000 tons per annum as a serious drain. The large discoveries in various parts of the world, greater facilities in transit, more extended use of petroleum and water power, would all help the present reserves to hold out.—Mr. J. Morley thought that the author had not taken thin seams into sufficient consideration in his estimates, and pointed out the economies in the iron and steel trades, but this is more than counterbalanced by the greatly increased production of iron.

II.—*AUSTRIA-HUNGARY.*

Mineral Statistics.—The following are the official returns relating to the production of the mines and works of the Austrian Empire, exclusive of Hungary, during the year 1888: *—

Divisions.	Iron Ore.	Forge Pig Iron.	Foundry Pig Iron.	Total Pig Iron.	Per cent. of Total Pig Iron Production.
	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.	Metric Tons.
Bohemia . . .	355,086	116,466	20,827	137,293	23·42
Lower Austria . .	6,148	43,824	5,162	48,986	8·36
Salzburg . . .	6,573	...	2,486	2,486	0·42
Moravia . . .	30,886	124,249	29,513	153,762	26·23
Silesia . . .	2,633	40,738	3,657	44,395	7·58
Styria . . .	511,934	147,019	2,130	149,149	25·45
Carinthia . . .	72,811	39,457	840	40,297	6·88
Tyrol . . .	4,865	1,734	1,362	3,096	0·53
Carniola . . .	9,545	3,331	570	3,901	0·66
Galicia . . .	8,839	...	2,756	2,756	0·47
Totals . .	1,009,320	516,818	69,303	586,121	100·00

The following divisions of the Empire showed an increased production of pig iron as compared with that of the preceding year:—

Divisions.	Metric Tons.	Per cent.
Bohemia	11,954	9·53
Lower Austria	17,198	54·10
Salzburg	1,085	77·40
Moravia	3,536	2·35
Silesia	8	0·02
Styria	38,685	35·02
Carinthia	1,253	3·21
Tyrol	1,754	130·65
Galicia	169	6·53

The production in Carniola diminished by 1298 tons, or 24·97 per cent.

Of the 125 existing blast-furnaces, 67 were in blast for 2969 weeks. At the ironworks 10,909 workpeople were employed, and at the iron ore mines 4404.

The production of coal in the Austrian Empire, excluding Hungary,

* *Statistisches Jahrbuch des k.k. Ackerbauministeriums für* 1888.

amounted in 1888 to 8,274,461 tons, valued at £1,997,526; the production of lignite being 12,860,255 tons, valued at £1,728,423. The coke produced amounted to 567,826 tons, valued at £326,449. Of graphite 19,646 tons, valued at £52,895, were produced.

The manganese ore produced amounted to 6554 tons, valued at £8099.

Bosnia.—The British Consul at Lerajevo reports that the Bosnian Mining Company last year closed their manganese mines at Cevljanovic as prices were too low. The chrome mines at Dubostica produce two or three thousand tons annually, but the mines in the immediate neighbourhood are getting worked out. There appears to be abundance of chrome ore in Bosnia.*

III.—*BELGIUM.*

Coal.—The production of coal in Belgium † amounted to 19,218,481 tons in 1888, as compared with 18,378,624 tons in 1887, showing an increase of 839,857 tons. The aggregate value was £6,480,723 for 1888, as compared with £5,906,962 in the previous year. The production by provinces was as follows:—

	1888.	Mines Working in 1888.
	Tons.	
Hainaut	13,993,140	184
Namur	428,173	13
Liége	4,797,168	71
Total	19,218,481	268

The number of workpeople employed was 103,477, and the average annual wages was £34, 15s.

Imports and Exports.—The imports of iron, steel, coal, &c., during the first six months of 1889, compared with those for the corresponding period of 1888, were as follows:—

* *Engineering*, vol. xlviii. p. 315.

† *Industries*, vol. vii. p. 256.

V.—*FRANCE.*

Iron and Steel.—The production of pig iron for the first half of 1889 is stated to have been as follows :*—

Description.	Forge Pig Iron.	Foundry Pig Iron.
	Tons.	Tons.
Coke pig iron	644,259	201,935
Charcoal pig iron . . .	3,643	1,025
Mixed brands	...	2,955
Totals	647,902	205,915
Totals in first half of 1887 .	651,982	169,842
Increase or decrease . .	−4,080	+36,073

The total production of pig iron thus amounted to 853,817 metric tons, against 821,824 tons in the first half of 1888, the increase being 31,993 tons.

The production of manufactured iron was as follows :—

Description.	First Half 1889.	First Half 1888.	Increase or Decrease.
	Tons.	Tons.	Tons.
Puddled rails	273	219	+54
Merchant iron, puddled . . .	264,272	288,529	...
„ „ charcoal . . .	3,897	4,788	...
„ „ obtained by reheating	65,463	81,644	...
Total merchant iron .	333,632	374,961	−41,329
Plates, puddled	49,110	46,348	...
„ charcoal	937	1,733	...
„ by reheating	3,513	4,815	...
Total plates . . .	53,560	52,896	+664
Total production . .	387,465	428,076	−40,611

* *Bulletin du Comité des Forges,* No. 249, pp. 58–62.

The French production of steel over the same period was as follows:—

Description.	First Half 1889.	First Half 1888.	Increase or Decrease.
	Tons.	Tons.	Tons.
Rails, Bessemer	75,412	83,538	...
,, open-hearth . . .	3,549	3,537	...
Total rails . . .	78,961	87,075	− 8,114
Merchant steel, Bessemer . .	52,529	46,905	...
,, ,, open-hearth .	54,794	41,796	...
,, ,, puddled . .	12,177	13,061	...
,, ,, cement . .	776	686	...
,, ,, crucible . .	5,493	4,304	...
Total merchant steel .	125,769	106,752	+ 19,017
Plates, Bessemer	15,192	17,925	...
,, open-hearth . . .	21,820	22,655	...
,, miscellaneous . .	4,346	5,217	...
Total plates . .	41,358	45,797	− 4,439
Total steel . .	246,088	239,624	+ 6,464

Coal.—The output of the French collieries is stated * to have been as follows:—

Description.	First Half 1889.	First Half 1888.	Increase or Decrease.
	Tons.	Tons.	Tons.
Coal and anthracite	11,696,020	10,860,925	+ 835,095
Lignite	210,954	216,796	− 5,842
Totals . .	11,906,974	11,077,721	+ 829,253

Imports and Exports.—The French imports and exports of iron ore, iron, and steel are stated † to have been as follows:—

* *Bulletin du Comité des Forges*, No. 249, pp. 55–57. † *Ibid.*, No. 249, pp. 51–52.

Description.	Imports during the First Half of		Exports during the First Half of	
	1889.	1888.	1889.	1888.
Iron ore	641,003	567,431	112,397	144,185
Pig iron	9,167	12,826	25,993	15,471
Manufactured iron .	5,773	7,281	45,432	15,929
Steel	2,156	2,649	13,396	6,596

Of iron imported and exported after manufacture, the tonnage was as follows:—

Description.	Imports during the First Half of		Re-exports during the First Half of	
	1889.	1888.	1889.	1888.
Forge pig iron . .	25,631	42,043	21,733	33,107
Foundry pig iron .	29,466	19,509	27,237	14,234
Totals . .	55,097	61,552	48,970	47,341
Charcoal iron . .	1,530	781	1,960	847
Coke iron . . .	2,653	2,747	1,965	2,654
Plates	2,035	1,764	1,464	1,954
Totals . .	6,218	5,292	5,389	5,455
Steel	2,420	2,584	1,068	1,121

The total amount of the imports of iron and steel during the first half of 1889 was 80,831 tons, that is, 11,353 tons, or 12·40 per cent. less than the corresponding figure for 1888.

The Iron Industry of France.—The ironworks of France may be grouped in four districts—the North, with such works as Anzin, Denain, Marchiennes, Maubeuge, Marquise, Fiveslille; the Centre, with Creuzot, Commentry, St. Chamond, Firminy, Fourchambault; the South, with La Voulte, Bessèges, St. Louis; and the East, with Longwy, Pont-à-Mousson, Stenay, and St. Dizier. The following tables relating to the iron trade of France are grouped according to these districts:—

Output of Coal in 1888.

Districts.	Metric Tons.
North—	
Nord and Pas de Calais	12,364,085
Centre—	
Loire	3,357,817
Saône-et-Loire	1,611,057
Allier	988,529
Isère	128,700
Cher	...
South—	
Gard	1,827,707
Aveyron	809,567
Other districts	1,293,351
Total	22,380,813

The production of pig iron was as follows :—

Production of Pig Iron in France in 1882, 1887, *and* 1888.

Districts.	1882.	1887.	1888.
North—			
Nord	255,322	223,315	231,693
Pas-de-Calais	53,126	97,920	85,391
Totals	308,448	321,235	317,084
Centre—			
Loire	58,547	31,536	34,161
Saône-et-Loire	177,740	55,001	70,107
Allier	90,507	28,151	18,090
Rhône	89,437	8,700	14,368
Cher	17,959	4,590	14,525
Isère	36,763	13,307	13,945
Totals	470,953	141,285	165,196
South—			
Gard	144,818	73,789	54,994
Aveyron	33,388	6,746	6,465
Ardèche	103,316	47,214	37,933
Bouches-du-Rhône	25,739	13,536	21,250
Ariège	22,150	9,632	7,364
Totals	329,411	150,917	128,006
East—			
Meuse	9,767	5,762	3,090
Meurthe-et-Moselle	716,043	770,842	911,009
Haute-Marne	82,865	63,148	43,589
Ardennes	22,258	18,298	20,475
Totals	830,933	858,050	978,163

The quantity of charcoal pig iron made in 1888 was 22,792 tons, nd of foundry iron 382,046 tons.

The following table shows the production of rolled iron in the same districts :—

Production of Rolled Iron in France in 1882, 1887, *and* 1888.

Districts.	1882.	1887.	1888.
North—			
Nord	335,442	285,631	303,541
Pas-de-Calais	308	325	430
Totals	335,750	285,956	303,971
Centre—			
Loire	84,280	37,361	37,111
Saône-et-Loire	64,949	68,126	71,564
Allier	38,378	29,360	31,631
Cher	570	560	627
Isère	14,833	5,155	4,009
Nièvre	20,373	5,049	6,672
Totals	223,383	145,611	151,614
South—			
Gard	27,916	14,870	14,103
Aveyron	19,986	11,562	10,200
Bouches-du-Rhône	1,567	880	1,457
Ariège	16,537	6,361	5,331
Totals	66,006	33,673	31,091
East—			
Meuse	20,103	7,993	10,717
Meurthe-et-Moselle	49,111	42,168	42,368
Haute-Marne	90,773	61,657	88,718
Ardennes	79,961	64,290	67,851
Totals	239,948	176,108	209,654

The following table shows the production of steel rails during the years 1882, 1887, and 1888: *—

Districts.	1882.	1887.	1888.
	Metric Tons.	Metric Tons.	Metric Tons.
North	59,529	114,620	94,863
Centre	170,208	4,747	5,098
South	106,461	32,145	23,481
East	...	25,183	21,818
Landes	...	26,113	30,313
Total product	336,198	202,808	175,573†

* *Iron Age*, vol. xliv. p. 370. † 175,598 in original.

The following table shows the progress of the steel trade of France since 1882:—

Production of Steel in France in 1882, 1887, *and* 1888.

Districts.	1882.	1887.	1888.
North—			
Nord	61,853	87,664	95,212
Pas-de-Calais	...	61,462	50,985
Totals	61,853	149,126	146,197
Centre—			
Loire	132,529	54,536	67,619
Saône-et-Loire	101,320	45,519	48,746
Allier	23,301	11,527	10,360
Isère	8,739	4,321	3,859
Nièvre	5,731	9,897	9,072
Totals	271,620	125,800	139,653
East—			
Meuse	51	5,558	6,155
Meurthe-et-Moselle	1,616	41,265	37,814
Haute-Marne	...	9,160	16,327
Ardennes	171	18,218	21,096
Totals	1,838	74,201	81,392
South—			
Gard	83,579	40,534	34,722
Aveyron	25,803	...	...
Ariège	6,223	3,496	2,087
Totals	115,605	44,030	36,809

VI.—*GERMANY*.

Production of Pig Iron.—The following table shows the production of pig iron in Germany during the first half of 1889 *:—

	Metric Tons.
Forge pig iron and spiegeleisen	981,806
Foundry pig iron	253,355
Acid Bessemer pig iron	198,704
Basic Bessemer pig iron	658,511
Total	2,092,376

* Compiled from the statistics published monthly in *Stahl und Eisen*.

Wrought Iron and Steel.—The production of wrought iron in the year 1887 amounted to 172,834 tons, and that of steel to 73,262 tons, the total being 246,096 tons for the two. The number of workmen employed was 11,714.

VIII.—*JAPAN.*

Iron in Japan.—In his report upon the trade and shipping of Yokohama during the year 1887, Mr. Quin, the British Consul, states that the value of the imports and exports compares favourably with that of the previous year, the former having been £5,568,633, as compared with £4,131,993, and the latter £5,347,743, as compared with £5,308,136. In metals, the value of the total trade of the port for 1887 exceeded that for 1886 by nearly 40 per cent., and was generally of a satisfactory character, the largest increase being in the following articles:—Iron rails, £101,913, against £86,720 in 1886; iron pipes of the value of £66,299, and ironware, which was imported to the value of £101,324, against £39,427 in 1886; also galvanised and roofing iron of the value of £10,479. Railway extensions are still absorbing a large quantity of rails, most of which, though included in the Customs returns as iron, should be called steel rails. The large import of iron pipes is accounted for by the requirements of Yokohama for a system of waterworks which has been successfully completed, and is not likely to appear again in the returns, unless the scheme talked of for Tokio be decided upon. The increase in ironware is accounted for by the importation of numerous heavy bridges and other ironware connected with railway works. Of the item £33,872 for engines, &c., over £16,000 was for locomotives, thus swelling the railway requirements to about £120,000. The import of galvanised iron, both corrugated and flat, has more than doubled. On the other hand, the consumption of pig iron, tin-plates, and steel has fallen off. Of the pig iron imported, Italy is credited with about 400 tons.

IX.—*NATAL.*

Coal in Natal.—Steam machinery is employed at the Elandslaagte Colliery only in Natal.* The existence of coal in this district has been known for several years, and it was mined by the military during

* *Natal Witness*, through *Iron and Coal Trades Review*, vol. xxxix. p. 521.

Steel.—There were in 1888, 34 works which possessed 17 converters, 67 open-hearths, 34 cementation furnaces, and 282 crucible furnaces. From the steel manufactured, 114,000 tons of rails and 9219 tons of plates and sheets were made. The maximum production was in the St. Petersburg district, which produced 75,059 tons, the next important districts being Jekaterinoslav and Warsaw, where the production was, respectively, 46,118 and 25,956 tons.

One half of the bituminous coal produced was obtained from the kingdom of Poland, and the greater part of the remainder from the Donetz basin, which latter was the sole source of the supply of anthracite. Lignite was chiefly obtained from Poland and the Moscow basin. The total quantity raised was 74,399 tons, of which 69,377 were obtained from the government of Kutaïs. The greater portion of the ore raised—54,440 tons—was exported from Batoum and Poti.

The workpeople employed at the iron mines and smelting works numbered 197,488, and at the collieries 33,158.

Petroleum Exports.—The petroleum exports from Russia were as follows in 1888, the exports for 1887 being also shown for the purpose of comparison :—

Description.	1888.	1887.
	Pud.	Pud.
Naphtha, crude	74,000	923,000
Vaseline and paraffin	3,000	6,000
Refined petroleum	26,651,000	11,191,000
Lubricating oils, crude	1,280,000	1,663,000
„ „ refined	1,421,000	1,076,000
Residues	4,417,000	3,211,000
Totals	33,846,000	18,070,000

A pud is approximately 36⅛ lbs. The exports for 1888 show, it will be seen, an increase of about 87 per cent.

The imports of Russian petroleum into British India have increased from 1,577,000 gallons in 1886 to 17,516,000 gallons in 1888–89. These figures compare with the United States imports into India of 29,000,000 gallons in 1886–87, and 20,000,000 gallons in 1888–89.*

* *Journal de St. Pétersbourg*, June 1889.

XII.—*SPAIN.*

Mineral Statistics.—The iron trade statistics of Spain for the year 1887 show that the quantities of minerals and metals produced were as follows: *—

Description.	Metric Tons.	Value.
Iron and steel . . .	288,704	£1,585,451
Iron ore	6,796,266	820,988
Manganese ore . . .	1,460	1,496
Coal	1,021,254	331,377
Lignite	17,051	8,385
Briquettes and coke . .	134,536	431,635

Exports of Pig Iron and Iron Ore.—The *Bilbao Maritima y Comercial* states that the exports of pig iron and iron ore from Spain in the years 1886, 1887, and 1888 have been as follows :—

Description.	1886.	1887.	1888.
	Metric Tons.	Metric Tons.	Metric Tons.
Pig iron . . .	49,420	115,359	73,677
Iron ore . . .	4,187,527	5,215,713	4,563,779

The exports of iron and iron ore from Spain during the first six months of 1889 were as follows, the figures for the corresponding periods of 1887 and 1888 being also given :—

Description.	1889.	1888.	1887.
	Metric Tons.	Metric Tons.	Metric Tons.
Iron ore . . .	2,656,171	2,375,875	2,713,763
Pig iron . . .	28,900	34,863	59,288

Accidents in Spanish Mines.—In 1887 there were employed at iron mines in Spain, 3001 workpeople. The accidents number 53, the killed numbering 16, and the injured 46. In coal mines 6322 workpeople were employed, and of these 14 were killed and 645 injured,

* *Revista Minera*, vol. xl. p. 219.

the total number of accidents amounting to 306; only one death was due to an explosion of fire-damp.*

XIII.—*UNITED STATES.*

Production of Pig Iron.—The following statistics relating to the production of pig iron in the United States in the first six months of 1889 have been prepared by the American Iron and Steel Association:—

Total Production of Pig Iron.

States.	Production in Tons of 2000 lbs. (includes Spiegeleisen). First Half of 1888.	Second Half of 1888.	First Half of 1889.
Maine	2,550	3,024	2,700
Massachusetts	7,005	6,243	2,651
Connecticut	10,236	11,408	12,108
New York	134,900	122,280	144,613
New Jersey	50,393	51,489	67,749
Pennsylvania	1,630,845	1,958,341	2,012,804
Maryland	6,250	11,356	10,233
Virginia	92,495	104,901	112,328
N. Carolina	1,100	1,300	922
Georgia	23,658	15,739	11,338
Alabama	169,696	279,796	364,346
Texas	2,968	3,619	1,411
West Virginia	45,601	49,658	72,775
Kentucky	21,267	35,523	23,865
Tennessee	122,817	145,114	147,401
Ohio	528,536	575,282	602,476
Indiana	7,300	7,960	7,806
Illinois	294,520	284,787	282,153
Michigan	106,578	106,673	100,363
Wisconsin	51,477	64,560	74,065
Missouri	60,789	30,994	42,795
Minnesota †	...	...	...
Colorado	11,522	9,355	...
Oregon	...	2,509	5,426
California ‡	...	...	...
Washington Territory	...	4,093	5,571
Totals	3,382,503	3,886,004	4,107,899
Anthracite	955,448	970,281	917,611
Charcoal	278,238	320,551	306,780
Bituminous	2,148,817	2,595,172	2,883,508
Totals	3,382,503	3,886,004	4,107,899

* *Revista Minera*, vol. xl. p. 221. † A blast furnace building. ‡ Furnace idle.

Total Production of Bessemer Pig Iron.

States.	Production in Tons of 2000 lbs. (includes Spiegeleisen).		
	First Half of 1888.	Second Half of 1888.	First Half of 1889.
New York	18,732	33,342	29,233
New Jersey	14,585	12,820	13,946
Pennsylvania	746,479	1,024,065	990,239
West Virginia	38,557	45,576	63,042
Tennessee	2,315	...	...
Ohio	138,828	197,927	207,407
Illinois	275,675	275,401	247,101
Missouri	54,144	22,376	37,080
Michigan	3,000	...	...
Wisconsin	17,136	17,400	1,625
Colorado	10,478	5,566	...
Totals	1,319,929	1,634,473	1,589,673

The quantity of spiegeleisen and ferromanganese made in the first half of 1888 was 21,162 tons (of 2000 lbs.); in the second half, 33,607 tons; in the first half of 1889, 34,760 tons.

The total stocks of pig iron at June 30, 1889, amounted to 563,286 tons.

Bessemer Steel Production.—The American Iron and Steel Association has received from the manufacturers complete statistics of the production of Bessemer steel ingots and Bessemer steel rails in the United States in the first half of 1889.* The following table shows the production of Bessemer steel ingots in the first half of 1889 compared with the production in each half of 1888. The production of steel ingots by the Clapp-Griffiths process is included, but a statement is also added of the ingots produced by this process alone:—

Ingots.	First Half of 1888.	Second Half of 1888.	First Half of 1889.
	Tons of 2000 lbs.	Tons of 2000 lbs.	Tons of 2000 lbs.
Pennsylvania	729,993	862,636	930,748
Illinois	321,115	299,741	245,171
Other States	333,180	265,835	244,796
Totals	1,384,288	1,428,212	1,420,715
Clapp-Griffiths only	36,070	45,087	38,356

* *Bulletin of the American Iron and Steel Association*, vol. xxiii. No. 25.

The following table shows the production of Bessemer steel rails of all kinds and sizes in the first half of 1889 compared with the production in each half of 1888, excepting a few thousand tons of Bessemer steel rails which were rolled in iron rolling mills from purchased blooms.

Rails.	First Half of 1888.	Second Half of 1888.	First Half of 1889.
	Tons of 2000 lbs.	Tons of 2000 lbs.	Tons of 2000 lbs.
Pennsylvania	420,101	491,105	523,882
Illinois	256,823	231,816	179,201
Other States	98,337	31,650	16,489
Totals	775,261	754,571	719,572

Imports of Iron Ore, Iron, and Steel.—The official report of the United States Bureau of Statistics shows that the quantity of iron ore imported during the fiscal year ending June 30, 1889, amounted to 653,206 tons, valued at 1,507,658 dollars, as compared with 919,644 tons in 1887–88, valued at 1,818,034 dollars. The imports of iron and steel were as follows:—

Value of Iron and Steel Imports.

Articles.	1889.	1888.
	Dollars.	Dollars.
Pig iron	2,860,462	5,042,886
Scrap iron	394,904	1,957,135
Scrap steel	55,432	161,014
Bar iron	1,135,665	1,219,461
Iron rails	481	5,375
Steel rails	581,109	3,219,212
Cotton-ties, iron and steel	897,762	528,334
Hoop iron	7,314	295
Steel hoops, sheets, and plates	902,456	831,941
Steel blooms, billets, and bars	2,460,390	4,442,647
Sheet and plate iron	447,016	531,484
Tin plates	21,222,653	18,979,344
Wire rods	2,500,394	3,648,480
Wire and rope wire	638,554	600,988
Anvils, axles, and forgings	164,292	182,743
Chains	84,600	97,506
Cutlery	2,362,537	2,210,736
Files, rasps, and floats	65,233	64,956
Fire-arms	1,159,147	1,070,685
Machinery	2,445,379	2,079,381
Needles	288,600	316,295
All other	1,708,462	1,801,859
Totals	42,377,842	48,992,757

So far as they are stated in the statistical returns, the quantities of iron and steel imported were as follows, in statute tons:—

Quantities of Iron and Steel Imported into the United States.

Articles.	1889.	1888.
	Tons.	Tons.
Pig iron	183,256	325,517
Scrap iron	34,217	142,087
Scrap steel	4,224	13,019
Bar iron	30,884	33,153
Iron rails	20	225
Steel rails	24,257	136,799
Cotton-ties	32,435	19,061
Hoop iron	262	9
Steel hoops, sheets, and plates	20,868	22,421
Steel blooms, billets, and bars	96,264	185,397
Sheet and plate iron	6,885	7,215
Tin-plates	328,454	283,457
Wire rods	80,451	120,955
Wire and wire rope	3,491	3,172
Anvils, axles, and forgings	1,222	1,298
Chains	722	922
Totals	847,912	1,294,707

The *Iron Age** has compiled from the official reports the following table showing the imports of iron and steel into the United States in the first half of 1889, compared with the first half of 1888:—

Materials.	Statute Tons.	
	First Half-year 1889.	First Half-year 1888.
Tin-plates	175,615	145,569
Pig iron	83,279	97,260
Steel blooms, &c.	48,609	56,094
Wire rods	40,110	61,472
Scrap iron	18,818	29,390
Bar iron	11,847	12,460
Steel plates, &c.	8,717	11,278
Steel rails	6,118	44,877
Cotton-ties	4,099	2,415
Sheet and plate iron	3,623	2,910
Wire and wire rope	1,853	1,530
Forgings, &c.	789	746
Scrap steel	730	5,685
Chains	294	411
Hoop iron	6	(344 lbs.)
Iron rails	...	1
Totals	404,507	472,098
Iron ore	391,905	326,169

* Vol. xliv. p. 247.

Exports of Iron and Steel.—The official returns relating to the exports of iron and steel from the United States in the fiscal years ending June 30, 1888 and 1889, are as follows:—

Value of Iron and Steel Exports from the United States.

Articles.	1889.	1888.
	Dollars.	Dollars.
Pig iron	228,945	174,414
Band and hoop iron	1,473	4,152
Bar iron	48,539	43,423
Wheels	74,465	108,882
Castings	369,535	264,492
Cutlery	102,252	115,408
Firearms	820,933	593,321
Steel bars	22,968	14,161
Locks and builders' hardware	1,700,390	1,442,635
Machinery	7,166,748	5,519,893
Cut nails	290,807	310,197
Wire nails, including tacks	157,339	155,403
Iron plates and sheets	28,620	198,024
Steel plates and sheets	2,601	6,746
Printing-presses	223,900	186,989
Iron rails	240	2,575
Steel rails	235,377	175,692
Saws and tools	1,980,878	1,659,727
Scales and balances	301,486	325,488
Sewing machines	2,247,875	2,245,110
Fire engines	10,175	1,300
Locomotives	1,227,149	407,014
Stationary engines	133,473	197,040
Boilers	267,394	238,726
Stoves and ranges	273,261	263,730
Wire	594,616	466,355
All other iron and steel	2,643,213	2,642,127
Totals	21,154,652	17,763,034

Condition of the Blast Furnaces.—At July 1, 1889, there were in blast in the United States 285 blast furnaces out of the total existing number of 544. The weekly capacity of the 285 furnaces in blast was 141,419 tons, and of the 259 which were out of blast, 69,367 tons. The following table shows the condition of the blast furnaces using coke as fuel at the date mentioned: *—

* *Iron Age*, vol. xliv. p. 53.

Coke Furnaces in the United States.

States.	Total Number of Furnaces.	Number in Blast.	Capacity per Week.	Number out of Blast.	Capacity per Week.
			Tons.		Tons.
New York	3	0	0	3	3,377
Pennsylvania:					
Pittsburgh district	19	18	21,056	1	1,462
Spiegeleisen	1	1	488	0	0
Shenango Valley	19	14	10,073	5	2,856
Juniata and Conemaugh Valleys	17	9	4,825	8	2,485
Spiegeleisen	1	1	700	0	0
Youghi. Valley	5	4	1,622	1	730
Miscellaneous	4	3	1,686	1	650
Maryland	1	0	0	1	179
West Virginia	6	3	2,418	3	488
Ohio:					
Mahoning Valley	14	11	8,700	3	1,738
Central and Northern	16	11	7,706	5	3,764
Hocking Valley	14	3	1,079	11	3,563
Hanging Rock	13	6	1,720	7	1,410
Indiana	2	0	0	2	389
Illinois	12	8	9,570	4	2,425
Spiegeleisen	1	1	600	0	0
Wisconsin	4	2	1,000	2	850
Missouri	6	2	1,094	4	2,218
Colorado	2	0	0	2	940
The South:					
Virginia	12	8	3,887	4	1,480
Kentucky	4	2	537	2	630
Alabama	26	21	13,278	5	2,262
Tennessee	11	7	3,900	4	1,200
Georgia	2	1	609	1	310
Totals	215	136	96,548	79	35,406

The following tables show the condition of the anthracite and charcoal blast furnaces at July 1:—

Anthracite Furnaces in the United States.

States.	Total Number of Furnaces.	Number in Blast.	Capacity per Week.	Number out of Blast.	Capacity per Week.
			Tons.		Tons.
New York	23	11	3,697	12	3,841
New Jersey	14	4	1,867	10	3,604
Spiegeleisen	3	3	218	0	0
Pennsylvania:					
Lehigh Valley	46	24	8,770	22	7,753
Spiegeleisen	1	1	75	0	0
Schuylkill Valley	32	14	4,992	18	5,231
U. Susquehanna Valley	17	7	2,724	10	1,753
Lebanon Valley	16	15	7,573	1	208
L. Susquehanna Valley	21	10	4,226	11	2,582
Totals	173	89	34,142	84	24,972

Charcoal Furnaces in the United States.

States.	Total Number of Furnaces.	Number in Blast.	Capacity per Week.	Number out of Blast.	Capacity per Week.
			Tons.		Tons.
New England . .	14	8	670	6	420
New York . .	10	3	412	7	520
Pennsylvania . .	23	4	310	19	749
Maryland . . .	8	3	325	5	240
Virginia . . .	23	4	250	19	696
West Virginia . .	3	0	0	3	165
Ohio	13	6	324	7	351
Kentucky . . .	2	2	220	0	0
North Carolina . .	2	1	70	1	70
Tennessee . . .	8	5	1,331	3	300
Georgia . . .	2	0	0	2	114
Alabama . . .	9	8	1,588	1	210
Michigan . . .	25	9	3,091	16	3,930
Missouri . . .	3	2	596	1	213
Wisconsin . . .	7	2	1,011	5	891
Texas . . .	1	1	173	0	0
California . . .	1	0	0	1	120
Washington . .	1	1	175	0	0
Oregon . . .	1	1	181	0	0
Totals . .	156	60	10,727	96	8,989

Iron Industry of New York.—A review of the iron industry of New York for the past decade is given by Mr. J. C. Smock.* The maximum of production was attained in 1882, after which there was a decline till 1885, and then a rise, with extraordinary outputs, during the last three years.

The iron ores of New York are grouped into seven districts. In the Highlands of the Hudson forty productive mines have been opened. The production of twenty-six mines in 1880 was 184,859 tons, and this decreased to 115,000 tons in 1888. Several mines have ceased to be worked, or are unproductive. The Lake Champion and Adirondack region, with ten idle mines, in 1880 produced 742,865 tons, but since then Chateaugay has been increasingly productive, and also the Port Henry mines. Accordingly, the output amounted to 812,000 tons in 1888. These two districts produce magnetites. The next, St. Lawrence and Jefferson Counties, produce red hæmatites. Three mines have been closed and two fresh ones opened, and the production has risen from 94,765 to 110,000 tons. Clinton and Wayne Counties

* *Transactions of the American Institute of Mining Engineers*, vol. xvii. pp. 745-750; No 7 *Bulletin of the New York State Museum of Natural History.*

Adirondack region has produced 15,147,000 tons since the commencement, of which 5,772,000 tons were produced in the past decade, and 789,419 tons in 1888. Bessemer ores are chiefly produced, and many of the lean ores are dressed.

The New Jersey mines show a decrease in production to 447,738 tons from 547,889 tons in 1887, and this is probably due to the competition with seaborne ores. The past decade has shown a production of over five and a half million tons: the total production is estimated at sixteen and a half million tons.

The Missouri district has taken a prominent place, and last year shipped 160,000 tons. There is also a rapid increase in the production of the Southern States, the output being probably about 2,500,000 tons. Of this Alabama contributed about 1,000,000 tons, Tennessee 615,000 tons, and Virginia between 450,000 and 500,000 tons. Ohio produces but little ore, the output in 1888 being 253,352 tons, which is a considerable decrease from the previous year.

Other states produce small amounts of ore. Of these Colorado gave 50,000 tons in 1888. Authentic records of imported ore are only obtainable since 1879, and show an increase from 284,141 tons in that year to a maximum of 1,194,301 tons in 1887, from which point the import fell to 587,470 tons in 1888. The total imports since 1879 have been 6,340,776 tons. Finally, the author arranges the iron ore producing regions in order of production both for 1888 and for the total output, and gives a series of curves which show the comparative yield of the various districts.

Iron Ore Production of New Jersey.—In his annual report, Mr. G. H. Cook, the State Geologist of New Jersey, compares the output of iron ore in the state in 1888 with the outputs of previous years. The total output in 1888 was 447,738 tons, a diminution of 100,051 tons as compared with the output of the previous year. The quantities raised in previous years are also given. In 1790 the output was about 10,000 tons, and in 1830 about 20,000 tons. In 1873 it reached 665,000 tons, but diminished again afterwards, until in 1876 it was but 285,000 tons. After this the output again increased, and reached its maximum in 1882, when it amounted to 932,762 tons.

The Cost of Production of Pig Iron.—Mr. C. A. Meissner* makes the following estimate of the relative cost of production of pig

* *Iron Age*, vol. xliv. p. 325.

iron in the State of Alabama and in the State of New York, the blast furnace being assumed to be in each case 65 feet high and 14 feet in diameter at the boshes, costing about £20,000 or £25,000 :—

Cost of Pig Iron per Ton in Alabama.

	Dollars.
2 tons of ore at 1.25 dollar	2.50
1½ ton of coke at 2.25 dollars	3.40
1 ton lime at 65 cents	0.65
Labour	1.60
Incidentals	0.25
Interest, 4 per cent. on total capital	0.20
Repairs	0.50
Total	9.10
Freight to New York	3.90
Total	13.00
Selling price at New York	16.00
Profit per ton	3.00

Average Cost of Pig Iron per Ton in Ohio and New York.

	Dollars.
Ore	5.50
Fuel	5.00
Lime	0.80
Labour	1.75
Incidentals	0.25
Interest	0.20
Repairs	0.50
Total	14.00
Average freight to New York	1.00
Total	15.00
Selling price at New York	16.00
Profit per ton	1.00

The Connellsville Coke Industry.—The following statement relating to the production of coke in the Connellsville district, United States, in 1889, has appeared in the Connellsville *Courier*:—

Months.	Tons of 2000 lbs.
January	524,447
February	417,280
March	443,090
April	418,534
May	454,250
June	421,178
	2,678,779

Basic Bessemer Process.—The following table is given by Professor W. B. Phillips * to show the increasing ratio of production of basic Bessemer steel in the world :—

Description.	1881.	1882.	1883.	1884.	1885.	1886.	1887.	1888.
Acid and basic	4,533,470	5,259,747	5,117,092	4,802,145	5,036,148	6,127,991	7,349,993	6,926,955
Basic . .	200,000	572,604	634,373	864,000	945,317	1,313,631	1,702,252	1,984,484
Acid . . .	4,333,470	4,687,143	4,482,719	3,938,145	4,090,831	4,814,360	5,647,741	4,942,471
Per cent. of ratio	4·44	10·83	12·39	18·00	18·80	21·50	23·15	29·10

Since 1878, when the process was started, over 8,000,000 tons of basic Bessemer steel has been produced, and of this total scarcely 50,000 tons has been made in the United States, while now it is not made at all. A suitable pig iron for this process contains carbon 2·5 to 3·0 per cent. ; phosphorus, 2·0 to 3·0 ; sulphur, upper limit, 0·6 ; silicon, upper limit, 1·5 ; manganese, 1·0 to 3·0 per cent. This kind of pig iron is not manufactured in the States, and it is difficult to find suitable ore, though investigations are now being made with some hope of success. The most favourable outlook for the process is in the Southern States, especially Alabama.

* *The Engineering and Mining Journal*, vol. xlviii. p. 30.

Mining.

Abel, Sir F. A. "*Mining Accidents and their Prevention.*" 8vo, pp. 431. New York. (Price 4 dollars.)

Brauner, J. C. "*Geological Survey of Arkansas: The Geology of the Coal Regions.*" 8vo, pp. 122. Illustrated.

Chalon, and J. Chansselle. "*L'électricité dans les mines.*" [Two reports presented to the International Mining and Metallurgical Congress, Paris Exhibition.] 8vo, pp. 29. Saint-Étienne.

Chatelier, H. Le. "*Lampes de sureté.*" [A report similar to the foregoing.] 8vo, pp. 88. Saint-Étienne.

Dujardin-Beaumetz. "*Histoire graphique de l'industrie houillère en Angleterre depuis* 1865." 4to, 20 plates. Paris. (Price 20 francs.)

Eissler, M. "*A Handbook of Modern Explosives.*" 8vo, 100 illustrations. London.

Fauck, A. "*Neuerungen in der Tiefbohrtechnik.*" 8vo, pp. 67, with 32 illustrations in the text, and 5 plates. Leipzig. (Price 4s.)

Fromentel, L. E. G. de. "*Description d'un nouveau ventilateur et son application à l'aération des mines.*" 8vo, pp. 28, with 1 plate. Gray. (Price 1.50 franc.)

Gordon, H. A. "*A Miner's Guide.*" 8vo, pp. 276. Wellington. New Zealand.

"*Guide du mineur à l'exposition universelle de* 1889." 8vo. pp. 214, and plan. Paris.

Horovsky, E. "*Deutsch- böhmisch- russisches berg- und hüttenmännisches Wörterbuch.*" 8vo. Prague.

Jones, E. A. "*The Southern Coalfields of the Satpura-Gondwána Basin.*" 8vo, pp. 158, with two coloured maps. Calcutta. (Price 4s. 6d.)

Mathet, F. "*L'air comprimé aux mines de Blanzy.*" 2nd edition. 8vo, pp. 144, with 6 plates. Saint-Étienne.

Ott, H. "*Die Möglichkeit des Vorkommens von Steinkohlen im Badischen Oberlande.*" 8vo, pp. 13. Landshut. (Price 6d.)

Potts, W. J. "*Mining Register and Directory for the Coal and Ironstone Trade of Great Britain and Ireland for* 1889." 8vo, pp. 319. North Shields. (Price 6s.)

Vollert, M. "*Der Braunkohlenbergbau.*" 8vo, pp. 402, with map. Halle.

Donations.	By whom Presented.
GERMANY.	
Grundriss der Eisen hüttenkunde. By Dr. Hermann Wedding. 1888.	The Author.
Der Umstand der Bergarbeiter im Niederrheinisch-Westfälischen Industriebezirk. By Dr. Gustav Natorp. Essen, 1889.	The Author.
Musterbuch für Eisen-constructionen. By C. Scherowsky. Berlin, 1889.	Herr Schrodter.
SWEDEN.	
Underdånig Berättelse anjående Konigl. Patentbyråus Verksamket. Hugo E. G. Hamilton.	
Betingelser för äudamålsenlig fromställening af Tackjernsgjutgods samt nya auväudmingar af Kiseljern af Professor Richard Åkerman.	The Author.
ITALY.	
Annali di Agricoltura. 1889.	The Minister of Agriculture.
Relazionie sul Servizio Minerario, nel 1887.	The Minister of Agriculture.
INDIA.	
Ceylon Administration Reports for 1888. Part IV. Miscellaneous Railways.	The Government.
UNITED STATES.	
The Chemical Analysis of Iron. By A. A. Blair.	The Author.
Report of the Railroad Commissioners of Iowa. 1888.	The Governor of Iowa.
Report of the Bureau of Labour Statistics, Conn. 1887.	The Bureau.
Notes on the Construction of Ordnance. Vol. II. 1889.	The Chief of Ordnance.
Reports of the Consuls of the United States. 1889.	The Bureau.
The Use of Metal Track on Railways as a Substitute for Wooden Ties. By E. Russell Tratman. 1888.	Department of Agriculture.
Statistics of the American and Foreign Iron Trades for 1888. (Annual Statistical Report of the American Iron and Steel Association.)	Mr. J. M. Swank.

The North of England Institution of Mining and Mechanical Engineers.
The Royal Dublin Society.
The Bristol Naturalists' Society.
The Mining Institute of Scotland.
The South Staffordshire Institute of Iron and Steel Works Managers.

"The Engineer."
"Engineering."
"Industries."
"The Ironmonger."
"The Iron and Coal Trades Review."
"Ryland's Iron Trade Circular."
"Iron."
"London Iron Trade Exchange."
"The Economist."
"The Statist."
"British Trade Journal."
"Martineau and Smith's Hardware Trade Journal."
"The Railway Engineer."
"The Contract Journal."
"The Shipping World."
"The Machinery Market."
"The Marine Engineer."
"Mechanical Progress."
"The Electrician."
"The Electrical Engineer."
"Railway News."
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AUSTRIA—

"Oesterreichische Zeitschrift für Berg- und Hüttenwesen."
"Berg- und Hüttenmännisches Jahrbuch."
"Jahrbuch der K.K. Geologischen Reichsanstalt."
"Wochenschrift des Oesterreichischen Ingenieur- und Architekten Vereines."

ITALY—

"Atti della reale Accademia dei Lincei."
"L'Industria."
"Bollettino del R. Comitato D'Italia."

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"Jernkontorets Annaler."
"Ingeniörs Föreningens Förhandlingar."

CANADA—

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"The Indian Engineer."
"Indian Engineering."

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"Journal of the Royal Society."

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"Revista Minera y Metallurgica."

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INDEX.

1889.

A

B

N

O

P

R

T

U

V

W

Z

THE END.

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THE

IRON AND STEEL INSTITUTE.

ESTABLISHED 1869.

LIST OF MEMBERS,

RULES, &c.

London:
VICTORIA MANSIONS, VICTORIA STREET.
1890.

THE

IRON AND STEEL INSTITUTE.

INDEX TO RULES.

APPENDIX.

THE IRON AND STEEL INSTITUTE.

RULES.

1. The Society shall be designated "THE IRON AND STEEL INSTITUTE."

2. The objects of the Institute shall be—

To afford a means of communication between members of the Iron and Steel Trades upon matters bearing upon their respective manufactures, excluding all questions connected with wages and trade regulations.

To arrange periodical meetings for the purpose of discussing practical and scientific subjects bearing upon the manufacture and working of iron and steel.

SECTION I.—**Constitution.**

3. The Institute shall consist of members who shall be more than twenty-one years of age, and shall have one or other of the following qualifications:—

(*a*) Persons practically engaged in works where iron or steel is produced or worked.

(*b*) Persons of scientific attainments in metallurgy, or specially connected with the application of iron and steel.

It shall be within the province of the Council to elect Honorary Members, the number not to exceed twenty.

SECTION II.—**Election of Members.**

4. A recommendation for admission according to Form A in the Appendix shall be forwarded to the General Secretary, and by him be laid before the Council. The recommendation shall be in writing, and be signed by not fewer than three members.

5. Such applications for admission as are approved by a majority of the Council shall be inserted on a voting list. This voting list shall specify the name, occupation, address, and proposers of the candidates, and shall be forwarded to the members at least fourteen days previous to the next general meeting, when the lists that have been returned to

purpose of considering the dissolution; and after confirmation by a similar vote, at a subsequent meeting, to be held not less than three, or more than six months after the first; and notice of this last meeting shall be duly advertised as the Council or a general meeting may advise.

APPENDIX.

FORM A.

Mr. A. B. (address in full), being of the required age, and desirous of becoming a member of the Iron and Steel Institute, we, the undersigned, from our personal knowledge, do hereby recommend him for election.

His qualifications are ____________________

____

Witness our hands this ______ day of ________ 18

______ ______ ______ } *Names of Three Members.*

FORM B.

Sir,—I beg to inform you that on the ____________ you were elected a member of the Iron and Steel Institute, but, in conformity with the Rules, your election cannot be confirmed until the accompanying form be returned with your signature, and until your entrance fee and first annual subscription (amount £________) be paid to me. If the first subscription is not received within two months of this date, your election will become void.

I am, Sir, your obedient Servant,

______________, *General Secretary.*

____day of ______18

FORM C.

I, the undersigned, being elected a member of the Iron and Steel Institute, do hereby agree that I will be governed by the regulations of the said Institute, as they are now formed, or as they may be hereafter altered; that I will advance the interests of the Institute as far as may be in my power; provided that, whenever I shall signify in writing to the Secretary that I am desirous of withdrawing my name therefrom, I shall (after the payment of any arrears which may be due by me at that period) be free from this obligation.

Witness my hand this ______ day of ______ 18

FORM D.

SIR,—I am directed to inform you that your subscription to the Iron and Steel Institute, amounting to ______, is in arrear, and that if the same be not paid to me on or before the ______ day of ______ 18______, your name will be removed from the lists of the Institute.

I am, Sir, your obedient Servant,

______, *General Secretary.*

LIST OF MEMBERS.

CORRECTED TO DECEMBER 31st, 1889.

HONORARY MEMBERS.

ÅKERMAN, PROFESSOR R., Bergsskolan, Stockholm.
BELGIANS, H.M. LEOPOLD II., KING OF THE, Brussels.
HEWITT, HON. ABRAM S., New York, U.S.A.
TUNNER, PETER RITTER VON, Leoben, Austria.
WALES, H.R.H. ALBERT EDWARD, PRINCE OF, K.G., K.T., K.P., G.C.B., G.C.S.I., &c., Marlborough House, Pall Mall, S.W.

ORDINARY MEMBERS.

*Those Marked * are Original Members.*

Elected Member	
1878	Abel, Sir Fredk. Augustus, C.B., F.R.S., *Royal Arsenal, Woolwich, S.E.*
1870	Adams, George, *Priestfields, near Wolverhampton.*
1869	*Adamson, Daniel, *The Towers, Didsbury, near Manchester.*
1872	*Addie, James, *Langloan Iron Works, Coatbridge, N.B.*
1869	*Addie, John, *Langloan Iron Works, Coatbridge, N.B.*
1889	Adler, Harmer, *Chicago, U.S.A.*
1880	Addyman, Thos., *West Gorton, Manchester.*
1888	Ainslie, Frank, *S. Lindal Moor Mines, Ulverston.*
1869	*Ainslie, W. G., M.P., 23 *Abingdon Street, London, S.W.*
1872	Ainsworth, George, *Consett Iron Works, Consett, County Durham.*
1887	Aird, John, 37 Great George Street, London, S.W.

Elected Member

1869 *Aitken, Henry,
Almond Iron Works, Falkirk, N.B.

1881 Akrill, Charles,
Golds' Green Foundry, West Bromwich.

1875 Albright, A.,
Mariemont, Birmingham.

1880 Alger, Charles,
Hudson, New York, U.S.A.

1887 Allan, George,
Corngreaves Works, Birmingham.

1883 Allan, T. A.,
The Tharsis Mines, Huelva, Spain.

1875 Allen, Alfred H.,
1 *Surrey Street, Sheffield.*

1880 Allen, H.,
Endcliffe, Sheffield.

1872 Allen, William Daniel,
Bessemer Steel Works, Sheffield.

1880 Allen, W. Edgar,
Imperial Steel Works, Saville Street, Sheffield.

1869 *Alleyne, Sir John G. N., Bart.,
Cevin, Belper.

1886 Alley, Stephen,
Sentinel Works, Glasgow.

1875 Alleyne, Reynold Henry Newton,
Leeds Old Foundry, March Lane, Leeds.

1879 Allison, Hy. Thos.,
Grosmont Iron Works, Grosmont, by York.

1874 Allport, Charles J.,
11 *Euston Square, London, N.W.*

1871 Allport, Howard Aston,
Dodworth Grove, Barnsley.

1889 Anderson, Alexander,
12 *Wellington Road, Old Charlton, S.E.*

1880 Anderson, C.,
3 *Belmont Grove, Leeds.*

1874 Anderson, Samuel,
Westbury Iron Works, Wiltshire.

1875 Anderson, William,
Lesney House, Erith, Kent.

1883 Anderson, W.,
Stockton-on-Tees.

1885 Andrew, Hy. Herbert,
Ranmoor, Sheffield.

1880 Andrew, J. A.,
Toledo Steel Works, Sheffield.

1873 Angus, Robert,
Lugar Iron Works, Cumnock, Ayrshire.

Elected Member	
1880	Annable, W., *Woodwill, Grimes Thorpe, Sheffield.*
1875	Anstice, R. E., *Madeley Wood, Iron Bridge, Salop.*
1869	*Armstrong, Lord, C.B., *Elswick Iron Works, Newcastle-on-Tyne.*
1885	Arrol, James C., 18 *Blythswood Square, Glasgow.*
1885	Arrol, Thomas A., *Germiston Iron Works, Glasgow.*
1883	Ascherson, E., 20 *Abchurch Lane, Cannon Street, E.C.*
1875	Ashbury, Thomas, *Ash Grove, Victoria Park, Longsight, Manchester.*
1887	Aspinall, Jno. A. F., *Fernbank, Heaton, Bolton-le-Moors.*
1883	Asthower, Frederick, *Ammen, Westphalia.*
1880	Atkinson, A. J., 44 *London Square, Bute Street, Cardiff.*
1889	Atkinson, Edward T., 24 *Erlanger Road, New Cross, S.E.*
1879	Atkinson, M. H., 21 *Windsor Terrace, Newcastle-on-Tyne.*
1882	Austin, Kenneth S., *Washwood Heath Road, Birmingham.*
1881	Baare, Fritz, *Bochum, Westphalia.*
1873	Bagley, Charles Jno., *Moor Iron Works, Stockton-on-Tees.*
1872	Bagnall, Thomas, *Grosmont Iron Works, viâ York.*
1877	Bagshawe, Washington, *Monkbridge Iron Works, Leeds.*
1887	Bailey, William H., *Salford, Manchester.*
1873	Bain, Sir James 3 *Park Terrace, Glasgow.*
1874	Bain, J. R., *Harrington Iron Works, Harrington, Cumberland.*
1880	Baird, Geo., *Fulmer, Slough.*
1869	*Baldwin, Alfred, *Wilden, near Stourport.*
1885	Bamforth, Thos., *Carron Works, Falkirk, N.B.*

Sussex.

ondon Bridge.

ampton.

Vorks, Attercliffe, Sheffield.

Vorks, Workington.

ampton.

n-in-Furness.

ton Road, Manchester.

hester.

iladelphia, U.S.A.

s Rivas, Bilboa, Spain.

treal, Canada.

r, Jefferson Co., Alabama, U.S.A.

Works, Carnforth.

ntataire, France.

k, U.S.A.

London, E.C.

Elected Member

1881 Bayliss, Moses,
St. Cuthbert's, West Heath Road, Hampstead, N.W.

1881 Bear, T. Drew,
113 *Queen Victoria Street, London, E.C.*

1880 Beard, A.,
Buildings, Swansea.

1886
Glasgow.

1882
and Steel Works, Glasgow.

1878
Mills, Glasgow.

1889
Steel Works, Sheffield.

1884
France.

1884
10, *St. Petersburgh.*

1881
Works, Sheffield.

1882
H.,
Knott Mill Iron Works, Manchester.

1889
k, Sheffield.

1874
P.,
Iron Works, Manchester.

1886
21 *Victoria Place, Stirling.*

1876 Bell,

1883 Bell, H. S.,
6 *Dents Road, Wandsworth Common, London, S.W.*

1869 *Bell, Sir Lowthian, Bart., F.R.S.,
Rounton Grange, Northallerton.

1889 Bell, Robert,
Clifton Hall, Ratho, Edinburgh.

1869 *Bell, Thomas,
Oakwood, Epping.

1869 *Bell, T. Hugh,
Clarence Iron Works, Middlesbrough.

1886 Bell,

1889
Manchester.

1888 Benne , mes,
12 *Hamilton Drive, Glasgow.*

1881 Benson, R. Seymour,
Hope Iron Works, Stockton-on-Tees.

Terrace, Darlington.

London, S.E.

debank, Glasgow.
orge
rentwood, Pendleton, Manchester.
rederick S.,
Sketty, Swansea.

Works, Spennymoor, County Durham.

1885 Blair, George Maclellan,
Clutha Iron Works, Glasgow.

1885 Blair, James Maclellan,
Clutha Iron Works, Glasgow.

1875 Blair, Thomas,
rd, Haymarket Chambers, Sheffield.

1878

1879
Road, Cardiff, Glamorganshire.

1881
lliam Street, London, E.C.

1878 Sanderson,

1869

1869
a, near Warrington.

1889
many.

1882
Germany.

1869
House, New Broad Street, London, E.C.

1869
Middlesbrough.

1880
y.

1884 W.,
argrave Hill, Henley-on-Thames.

1888 eorge,
wcastle Chambers, Nottingham.

1883 , Ludwig,
lgo-Tarjan, Hungary.

n,
Steel Castings Company, Openshaw, Manche

Iron Works, Manchester.

rescent, Glasgow.

nfield, Manchester.

Street, E.C.

ad, Wolverhampton.

Birmingham.

Sheffield.

J., Bart.,
rge Street, Westminster, S.W.

ne, London, W.

s, Dortmund, Germany.

Street, Sunderland.

Rome.
G. T.,
ei Bobrek Ober-Schlesien, Germany.

Plate Works, Cinderford.

Street, London, E.C.

near Manchester.

Edinburgh.

Altrincham, Manchester.

Porthcawl, near Bridgend.

Terrace, Gateshead-on-Tyne.

Huddersfield.
Burkill,
The Hagg, Wadsley Bridge.

Elected Member

1883
Works, Tolcross, Glasgow.

1877
Road, Lambeth, London, S.E.

1874
or, viâ Carnforth.

1872
B.

1873

1886 John,
Ealing Dean, W.

1889
pain.

1881 n.,
and Steel Company, Limited, Walsall.

1886 ustice,
Foundry, Walsall.

1883 G.,
Gouldon House, Shelton, Stoke-on-Trent.

1880
13 *Ainslie Place, Edinburgh.*

1884 Brundreth, Alex.,
orks, Rhymney.

1872
Westminster, S.W

1880 Brustlein,
d'Unieux, Loire, France.

1876
& Co. (Limited), Derby.

1888
Llanelly.

1887
Oldham.

1881 Buckton, Walter,
27 *Ladbroke Square, Notting Hill, W.*

1888 Budd, Edward Fraser,
Brierley Hill,

1872 Bull, James,

1872 ,
72 *Mark Lane, London, E.C.*

1886 Bullock, Cyrus,
67 *King Street, Manchester*

1888 Bullock, Joseph H.,
Pelsall Iron Works, Walsall.

1884 Bunning, Charles Z.,
3 *Richmond Hill, Norwich*

Elected Member

1882 C.,
Foundry, Glasgow.

1883
Steel Works, Loxley, near Sheffield.

1870 A.,
Troy, New York, U.S.A.

1881 Burn, R. Scott,
Oak Lea, Edgeley Road, near Stockport.

1873 L.,

1875
Club, Pall Mall, London, S.W.

1883

1876

1881
Woodlands, Wigan, Lancashire.

1880 Bush, George,
Rutland House, Lee Park, S.E.

1883 Bush, Dudley, J. C.,
Fort House, South Molton, North Devon.

1883 Butler, B. F.,
Forge, Leeds.

1872
Leeds.

1876
near Newport, Monmouthshire.

1874
House, Crockelty Road, Handsworth, Birmingh

1889
Ulverston.

1883
near Northampton.

1882
llingborough.

1889

1888
House, Shipley, Yorkshire.

1874 Henry,
The Farre Close, Brighouse, Yorkshire

1877 Campbell, Daniel,
Harbridge, Catford Hill, S.E

1869 *Carbutt, E. Hamer,
19 Hyde Park Gardens, W.

Elected Member	
1878	Carmont, William Haselwood, *Mansfield Chambers, St. Ann's Square, Manchester.*
1879	Carnegie, A., 23 *Broad Street, New York, U.S.A.*
1883	Carr, Edward, 59 *Sinclair Road, West Kensington Park, W.*
1871	Carrington, Arthur, *Wingerworth Iron Works, Chesterfield.*
1881	Carruthers, Ben., *Worsbro' Park, Barnsley.*
1880	Carson, W., *Wallasey, Birkenhead.*
1888	Carter, William Allan, 5 *St. Andrew Square, Edinburgh.*
1872	Cassels, Jno. R., *Glasgow Iron Works, Glasgow.*
1871	Cassels, Robert, 168 *St. Vincent Street, Glasgow.*
1877	Casson, Richard Smith, *Round Oak Iron Works, Brierley Hill.*
1882	Cavendish, Lord Edward, M.P., *Holker Hall, Grange, Lancashire.*
1886	Cawley, George. 358 *Strand, W.C.*
1889	Chadwick, David, 36 *Coleman Street, London, E.C.*
1876	Chambers, A. M., *Thorncliffe Iron Works, Sheffield.*
1872	Chanove, Gabriel, *Rue de la Thaina* 11, *Paris.*
1872	Chapman, Henry, 113 *Victoria St., Westminster, S.W., and* 10 *Rue Laffitte, Paris.*
1882	Chapman, John G., *Tower Hill, Middleton-One-Row, Darlington.*
1884	Charlton, Hy., *Gateshead Iron Works, Gateshead.*
1885	Charlton, Wm., *Guisbrough, Yorkshire.*
1877	Chatwood, Samuel, *Dronknaler Park, Prestwick, Lancashire.*
1872	Cheesman, Wm. T., *Hartlepool.*
1883	Cherrie, J. M., 21 *Hope Street, Glasgow.*
1882	Church, Richard F., M.I.C.E., 1 *Victoria Street, Westminster.*
1888	Clapp, Geo. H., 95 *Fifth Avenue, Pittsburgh, U.S.A.*

Elected Member	
1886	Claughton, Gilbert H., *Dudley.*
1874	Cleghorn, John, *Union Bank Chambers, Spring Gardens, London, S.W.*
1882	Cleminson, Jas., *Dashwood House, London, E.C.*
1888	Clerke, Wm., *Messrs. Grindlay & Co., Parliament Street, S.W.*
1869	*Cliff, Joseph, *Frodingham Iron Works, near Doncaster, Lincolnshire.*
1882	Cliff, Wm. D., *Wortley, Leeds.*
1875	Clive, Robert, *Clanway Colliery and Iron Works, Tunstall, Staffordshire.*
1879	Cochrane, Alfred O., *Coatham, Redcar.*
1869	*Cochrane, Charles, *Green Royde, Pedmore, near Stourbridge.*
1883	Coghlan, C., *Hunslet Forge, Leeds.*
1887	Coghlan, John H., *Grosvenor House, Headingley, Leeds.*
1884	Cole, Albert, *Brierley House, Brierley Hill.*
1888	Cole, John Wm., *c/o Jas. Martin & Co., Phœnix Foundry, Gawler, South Australia.*
1883	Colley, Alfred, *Sheffield Steel and Iron Works, Sheffield.*
1883	Collonette, R., *Cocken Villa, Walney Road, Barrow-in-Furness.*
1870	Colquhoun, James, *Tredegar Iron Works, Tredegar, Monmouthshire.*
1881	Colquhoun, James, Jun., *Stanton Iron Works, near Nottingham.*
1877	Colver, R., *Continental Steel Works, Sheffield.*
1883	Colville, D., Jun., *Motherwell, N.B.*
1880	Colville, John, *Motherwell, N.B.*
1886	Cook, Joseph, *Codnor Park, Alfreton.*
1879	Cook, Joseph, Jun., *Washington, County Durham.*
1874	Cooper, Arthur, *North Eastern Steel Works, Middlesbrough.*

Slip, New York, U.S.A.

Top, West Bromwich.

Crescent, Brighton.

russels.

oad, Regent's Park, London, N.W.
ohn,
n Court, Cornhill, E.C.

ane, Sefton Park, Liverpool.
tram,
Works, Spennymoor.

kirk, N.B.

sey, Manchester.
Edward,
rge Street, Westminster, S.W.

rge Street, Westminster, S.W.

hemical Works, Glasgow.

Dennistown, Glasgow.

Middlesbrough.

et, Manchester.

& Co., Darnall, Sheffield.

Road, Sheffield.

al and Iron Works, near Nottingham.
T. W.,
Alston, Cumberland.

Cardiff.

astle, Merthyr Tydvil.

leveland, O., U.S.A.

s, near Wigan.

Side, Workington.

, Nottingham.

uildings, London, E.C.

om, Cumberland.

, Glasgow.

nchester.

heshire.

lasgow.

rks, Kidderminster.

rland.

Spain.

l Coal Company, Ld., George Yar
reet, E.C.

eet, Glasgow.

e, N.B.

ks, Coatbridge, N.B.

rks, Manchester.
t,
ks, Glasgow.

üsseldorf, Germany.

West Lodge, Darlington.

Elected Member

1881 Dalgliesh, Richard,
The Limes, Asfordley, Melton Mowbray.

1886
Headingley, Leeds.

1874 Julien,

1887
wansea.

1889
Works, Brukdisponent, Sweden.

1882
ellington, Salop.

1880
near Wrexham.

1873

1889

1870
Glamorganshire.

1880 Davey, Henry,
3 Princes Street, Westminster, London, S.W.

1884 Davie, Thomas,
nd Steel Works, Coatbridge, N.B.

1874
, Stourbridge.

1889 Gustavus Silvester,
Bolckow, Vaughan & Co., Middlesbrough.

1882 B.,
Spain.

1889 Davies, William,
Sheffield.

1882
Abersychan, near Pontypool, Monmouth.

1875 Davis, Alfred,
's Mansions, Westminster, London, S.W.

1878
Iron Works, Ilkeston, near Nottingham.

1889
1 *Street West, King William Street, E.C.*

1883 Davy, Abraham,
The Oaks, Pitsmoor, Sheffield.

1889 Davy, Charles,
Park Iron Works, Sheffield.

1883 Davy, David,
Broom Croft, Parkhead, Sheffield.

Malvern Link, Worcester.
rederick,
ffices, Liverpool.

rn Railway, Swindon.

venue, Hampstead, N.W.
on,
Whitehaven.

, Hunslet, Leeds.

ontain à Outreau, Pas-de-Calais, France.

London, S.E.

Street, London, E.C.

lwyn, Herts.
B.,
.S.A.
Duke of, K.G.,
Grange, Lancashire.

Street, London, E.C.
ey,
' Works, Newton, near Glasgow.

Sunderland.

rrace, Jarrow.

on Works, Grosmont, Yorkshire.

ctoria Street, London, E.C.

1880 ,
Mines, Saltburn-by-the-Sea.

1874

, St. Petersburg, Russia.

1869
Cleveland Iron Shipyard, Middlesbrough.

1884 Benj.,
Bearpark Colliery, County Durham.

Elected Member

1869 *Dodds, Joseph,
Stockton-on-Tees.

1872 Dodds, Matthew B.,
Stockton-on-Tees.

1885 Donald, Wm. J. Alex.,
27 *St. Vincent Place, Glasgow.*

1874 Dorman, A. J.,
Middlesbrough.

1870 Douglas, C. P.,
Parliament Street, Consett, Durham.

1875 Dove, George, Jun.,
Hatfield House, Hatfield, near Doncaster.

1869 *Downey, Alfred C.,
Coatham Iron Works, Middlesbrough.

1877 Downie, Alexander,
The Ashes, Stanhope, Weardale.

1881 Downing, Samuel,
Morlands, Sutton Road, Erdington, Birmingham.

1889 Dreux, A.,
Acieries de Longwy, Mont St. Martin, France.

1888 Dronsfield, William,
Alexandra Park, Oldham.

1885 Drown, Thomas M.,
Institute of Technology, Boston, U.S.A.

1886 Dudley, Charles B.,
Altoona, Pennsylvania, U.S.A.

1889 Duncan, David John Russell,
10 *Airlie Gardens, Kensington, W.*

1888 Dunkerley, C. Chorlton,
Hurst Dale, Bowden.

1888 Dunlop, Alexander M.,
11 *Norfolk Street, Park Lane, London, W.*

1875 Dunnachie, James,
Glenboig, near Coatbridge, N.B.

1877 Du Pre, Francis Baring,
Oakwood, Chichester.

1875 Durfee, Wm. F.,
Pennsylvania Diamond Drill Coy., Birdsboro', Berks County, U.S.A.

1881 Durham, The Earl of,
Lambton Castle, Fence Houses, Co. Durham.

1884 Durieux, Aimé,
18 *Avenue Matignon, Paris.*

1884 Dyer, H. S.,
Condercum House, Newcastle-on-Tyne.

1875 Dyson, George,
Middlesbrough.

Elected Member

1885 Eadon, Robt. Renton,
President Works, Sheffield.

1882 Eagland, W. H.,
74 *Wellington Street, Leeds.*

1886 Earle, Wm. Norcliffe,
Cwm Avon, Port Talbot, S. Wales.

1882 Easton, Edward,
Delahay Street, Westminster, S.W.

1887 Eccles, Herbert,
Cwm Avon, Port Talbot, Glamorganshire.

1880 Edge, John H.,
, Shifnal, Salop.

1884
Woolwich.

1889
R.S.O., Glamorganshire.

1889
)., Glamorganshire.

1887
Columbia College, New York, U.S.A.

1880
ny.

1883
Works, Plymouth.

1877
rt., M.P.,
Street, London, S.W.

1885 Ellis, Arthur D.,
mpany, Bradford, Yorks.

1889 Ellis, [illegible]
Coy., Ld., New Glasgow, Nova Scotia.

1883 Ellis, E. William,
Church Place, New Swindon, Wilts.

1875 Ellis, J. D.,
Atlas Works, Sheffield.

1884 Ellis, T. L.,
North British Iron Works, Coatbridge, N.B.

1879 Elliso
Harrington, Cumberland.

1874 Euche
Paris.

1882
Merthyr Tydfil.

1873
Works, Barrow-in-Furness.

1889
Works, Barrow-in-Furness.

1881
Parliament Mansions, Victoria Street, London, S.W.

Elected Member

1878 Evans
Works, Consett, Durham.

1884
Grange, Rotherham.

1869
Works, Bradford, Yorkshire.

1882
Cyfarthfa Iron and Steel Works, Merthyr Tydfil, Glamorganshire.

1883 Evans, W.,
The Cliff, Ferryside, Carmarthenshire.

1889 Evrard, Alfred,
19 *Boulevard des Italiens, Paris.*

1869 *Farley Renben,
Foundry, West Bromwich.

1869
Works, Dudley.

1877 Faustman, E.,
Care of T. Nordenfelt, 53 *Parliament Street, London, S.W.*

1872 Faviell, F. H.,
ondon, E.C.

1886

1886
Glasgow.

1889 Fellows,
W

1889
Wm.,
Buchanan Street, Paisley.

1885
Coatbridge, N.B.

1889
London Bridge, S.E.

1888 Firth,
Works, Sheffield.

1882 Firth,
Sheffield.

1889 Firth,
Coy., Nicetown, Philadelphia, U.S.A.

1881
9, *Magdeburg, Germany.*

1883
, *Market Harborough.*

1870 Fisher, E. K.,
Market Harborough.

Elected

'errace, Barrow-in-Furness.

New York.

Works, Sheffield.

Street (West), Newcastle-on-Tyne.

Bathgate, Glasgow.

, viâ Carlisle.

y, Booth Street, Salford.

Swansea.

. O., Northumberland.

o., Chicago, U.S.A.

reet, London, E.C.

Vaughan & Co., South Bank, Middlesbrough.

on Works, Stourbridge.

the-et-Moselle, France.

ompany, Ouseburn, Newcastle-on-Tyne.

Company, Armley, Leeds.

d Engineering Co., Sydney, N.S.W.

teel Works, New Glasgow, Nova Scotia.

dgar,

Street, London, E.C.

Street, Glasgow.

Works, Coatbridge, N.B.

strasse 2, Vienna, Austria.

...tte, Regensberg, Bavaria.

Elected Member

1879 Fry, John E.,
Springfield Iron Works, Illinois, U.S.A.

1869 *Fry, Theodore, M.P.,
Darlington.

1884 Galbraith, Wm.,
Shelton Iron and Steel Co., Stoke-on-Trent.

1882 Galloway, Arthur Walton,
Knott Mill Iron Works, Manchester.

1870 Galloway, Charles John,
Knott Mill Iron Works, Manchester.

1885 Galloway, Ed. N.,
Knott Mill Iron Works, Manchester.

1875 Galloway, John, Jun.,
Knott Mill Iron Works, Manchester.

1882 Galton, Sir Douglas, C.B., D.C.L., F.R.S.,
12 *Chester Street, Grosvenor Place, London.*

1888 Gamble, Joseph,
Sheffield.

1879 Gargan, Baron de,
Hayange, Alsace-Lorraine, Germany.

1884 Garrett, Geo.,
Waverley Iron and Steel Works, Coatbridge, N.B.

1889 Garrison, F. Lynwood,
South-East Corner, 4th Chestnut Street, Philadelphia, U.S.A.

1875 Gautier, Ferdinand,
3 *Rue Legendre, Parc Monceau, Paris.*

1888 Gayley, James,
Edgar-Thomson Steel Works, Pittsburgh, U.S.A.

1884 Geen, Geo.,
Ivor Villa, Gold Tops, Newport, Monmouthshire.

1875 Gilchrist, P. C.,
Frognal Bank, Finchley New Road, Hampstead, N.W.

1869 *Gilkes, Gilbert,
Morny Hills, Kendal.

1870 Gill, William,
Norwood Lodge, Middlesbrough.

1881 Gill, William,
Orconera Iron Company, Bilbao, Spain.

1872 Gillott, Thomas,
Butterley Iron Works, Alfreton, Derbyshire.

1872 Gilmour, Allan,
Maryport Ironworks, Maryport.

1886 Gilmour, Allan, Jun.,
Maryport Iron Works, Maryport.

1869 *Gjers, John,
Ayresome Iron Works, Middlesbrough.

Elected Member	
1882	Gjers, Lawrence F., *3 Southfield Villas, Middlesbrough.*
1886	Gledhill, John M., *Sir Joseph Whitworth & Co., Manchester.*
1885	Glover, Ben Bradshaw, *Beech Bank, Newton-le-Willows, Lancashire.*
1879	Goldsworthy, R. B., *Hulme, Manchester.*
1871	Goldwyer, John E., *Witford House, Briton Ferry, Glamorganshire.*
1885	Goodchap, Charles A., 109 *Jermyn Street, London, S.W.*
1886	Goransson, A. H., *Sandviken Steel Works, Sweden.*
1887	Gordon, Alex., *Hamilton, Ohio, U.S.A.*
1881	Gordon, Andrew, *Cransley Iron Works, Kettering.*
1885	Gordon, Fred. W., 226 *Walnut Street, Philadelphia, Pa., U.S.A.*
1873	Gordon, Joseph G., *Queen Anne's Mansions, S.W.*
1880	Gössell, O., Jun., 110 *Cannon Street, London, E.C.*
1878	Gottschalk, Alexandre, 13 *Rue Auber, Paris.*
1887	Goudie, Robert, 14 *Alloway Place, Ayr, N.B.*
1887	Goulty, Wallis Rivers, *Albert Chambers, Albert Square, Manchester.*
1889	Graham, Alexander Macdougal, 20 *Dixon Street, Glasgow.*
1886	Grant, T. Maxwell, *Windlass Engine Works,* 100 *Hydepark Street, Glasgow.*
1869	*Granville, Earl, K.G., *Walmer Castle, Deal, Kent.*
1888	Grazebrook, Michael Hickman, *Netherton Iron Works, Dudley.*
1888	Green, Sir Edward, Bart., *Wakefield.*
1886	Green, Edward Llewellyn, *Fairy Land, Neath, South Wales.*
1881	Green, John, *Tin Plate Works, Abercarn, Monmouthshire.*
1885	Greenwood, William Henry, *Birmingham Small Arms and Metal Company, Adderley Park Works, Birmingham.*

Elected Member	
1889	Gregory, Joseph, *Whalley Cottage, Upper Chorlton Road, Manchester.*
1875	Greig, David, *Steam Plough Works, Leeds.*
1876	Greiner, A., *Société John Cockerell, Seraing, Belgium.*
1887	Griffin, S., *Cleveland House, Bath.*
1884	Griffith, W., *Sheffield.*
1886	Griffiths, Azariah, *Clyde Cottage, Falkirk, N.B.*
1874	Griffiths, N. R., *Wrexham.*
1872	Griswold, Chester, 11 *Pine Street, New York, U.S.A.*
1869	*Grove, Edwin, *Brendon View, Stow Park, Newport, Monmouthshire.*
1879	Gruson, H., *Buckau, Magdeburg, Germany.*
1875	Guest, Josiah, *Victoria and Albert Iron Foundries, West Bromwich.*
1889	Gubbins, R. R., *North Kent Iron Coy., Erith, Kent.*
1888	Guilleaume, Theodor, *Mulheim-on-the-Rhine, Germany.*
1882	Guilleaume, Emil, *Carlswerk, Mulheim-on-Rhine, Germany.*
1875	Gunther, William, *Central Engineering Works, Oldham.*
1883	Gutmann, Max Ritter von, *I Kantgasse, 6, Vienna, Austria.*
1878	Haarmann, August, *Osnabrück Iron and Steel Works, Osnabrück, Prussia.*
1887	Hackney, Samuel John, *Bott & Hackney, New Islington, Manchester.*
1885	Hadfield, Robt. Abbott, *Ashdell, Sheffield.*
1875	Hagerman, J. J., *Colorado Springs, Colorado, U.S.A.*
1884	Haggie, D. H., *Sunderland.*
1889	Haggie, Peter Sinclair, *Gateshead-on-Tyne.*
1878	Hall, J. F., *Norbury, Pitsmoor, Sheffield.*

Elected Member

1872 illiam F.,
aswell Colliery, Fence Houses, Durham.

1888
Iron Works, Lauchhammer, Germany.

1879 F. A.,
de Lyon, Paris.

1873 Druitt,
ictoria Chambers, London, S.W.

1885
Works, Newmains, N.B.

1881
7 Bishopgate Street Within, London, E.C.

1870 n, Thomas,
Steel Works, Barrow-in-Furness.

1888
Lueg, Dusseldorf, Germany.

1880
Ulverston.

1875 R. B.,
oor Oaks Road, Broomhill, Sheffield.

1884
Road, Broomhill, Sheffield.

1886
Steel Works, Sheffield.

1869
Works,

1884 .,
Mount Pleasant, Bilston, Staffordshire.

1869
N

1875
Works, Stoke-on-Trent.

1875
Works, near Burslem, Staffordshire.

1883
Middlesbrough.

1889
lesbrough.

1888 Harrison, George Herbert,

1876
Stourbridge.

1882
Cyclops Iron Works, Walsall.

1877 Hart, John,
New Exchange Buildings, Middlesbrough.

1888 Hartington, Right Hon. the Marquis of, M.P.,
Devonshire House, London.

Elected

effield.
M.,
th Front Street, Philadelphia, U.S.A.
n,
France.

Darlington.

Sheffield.

Park Villa, Wishaw, near Glasgow.
J. F.,
10, Vienna, Austria.

e, Kidderminster.

Hagley, Stourbridge.

ks, Middlesbrough.

treet, Westminster, S.W.

Works, Sheffield.

treet, Westminster, S.W.

e, South Hampstead.
l,
idge Company, Buffalo, U.S.A.
A.,
Iron Works, Stockton-on-Tees.

y Brothers, Newport, Monmouthshire.

Mills,

Anne's Gate, Westminster, S.W.

Manor, Newcastle, Staffordshire.

Hall, Newcastle,

Iron Works,
Jun.,
Iron Works, Stoke-on-Trent.

Elected Member	
1875	Heathfield, R., *Foxlydiate, near Redditch.*
1880	Hedley, Robt., *Tudhoe Iron Works, Spennymoor.*
1873	Hedley, Thomas, 2 *Fenham Terrace, Newcastle-on-Tyne.*
1884	Helder, Aug., *Whitehaven, Cumberland.*
1884	Hellon, Robt., 47 *New Lowther Street, Whitehaven.*
1878	Helmholtz, Otto, *Director of the "Gesellschaft für Stahl Industrie," Bochu Germany.*
1877	Helson, Cyriaque, *Etablissements Metallurgiques de MM. Vardy et Bene Savona, Italy.*
1889	Henderson, Norman M'Farlane, *Broxburn Lodge, Broxburn.*
1889	Henning, Gustavus, 16 *Cedar Street, New York, U.S.A.*
1884	Heslop, C., *Upleatham Mines, Upleatham, R.S.O., Yorkshire.*
1869	*Hewlett, Alfred, *Kirkless Hall Iron Works, Wigan.*
1873	Hewlett, W. H., *Wigan Coal and Iron Company, Wigan.*
1879	Heywood, H., *Cardiff.*
1879	Hick, John, M.P., *Mytton Hall, Whalley, Blackburn.*
1879	Hickman, A., M.P., 22 *Palace Gardens, Kensington, W.*
1883	Hickman, A. W., *Spring-Vale Furnaces, Wolverhampton.*
1881	Higginbottom, James, *Seel Street, Liverpool.*
1879	Higson, Jacob, 68 *New Bridge Lane, Stockport.*
1869	*Hill, Alfred C., *Southbank, R. S. O., Yorkshire.*
1878	Hill, Francis, *Stocksbridge, near Sheffield.*
1885	Hill, John, 4 *Oxford Terrace, Stockton-on-Tees.*
1886	Hill, Joseph, 6 *Hartington Street, Barrow-in-Furness.*
188[illegible]	Hills, Arnold F., *Thames Iron Works, London.*

Elected Member

1874

& Co., Middlesbrough.

1885

Penistone.

1883

Works, Dudley.

1889 amin,

Works, Dudley.

1886 Hirst,

Works, Dowlais.

1874

Park Road, Jarrow-on-Tyne.

1879

County Durham.

1884

238 Barnsley Road, Sheffield.

1878 Hodgson, John,

Darlington.

1873

Heaton-Moor, Stockport.

1886

1887

Road, Darwen.

1874 Holland, C. B.,

Ebbw Vale Works, Newport, Mon.

1889 nes,

ldham.

1873 T.,

Street, Strand, W.C.

1880

Lodge, Darlington.

1876

16 Rupert Street, St. James's, London, W.

1876 Holt, Henry Percy,

The Cedars, Didsbury, Manchester.

1871 J

1873 Hopkinson, John,

's Road, Bowden, Cheshire.

1886

near Glasgow.

1879

, Liverpool.

1876

27 Belgrave Road, London, S.W.

1888 Horsfield, Arthur,

High Bank, Horbury, near Wakefield.

Elected Member	
1889	Horsfield, Samuel, *Hallside Steel Works, Newton, N.B.*
1888	Horton, Enoch, *The Grange, Bescot, near Walsall.*
1883	Horton, S. B. L., *Park House, Shifnal, Salop.*
1869	*Horton, Thomas E., *Penmaenmawr, North Wales.*
1885	Hosking, Richard, *Clarence House, Dalton-in-Furness.*
1873	Houghton, John, *The Beeches, Moore, near Warrington.*
1880	Houldsworth, Jas., 36 *Queen's Gate, South Kensington, London.*
1882	Houldsworth, W. J., 36 *Queen's Gate, South Kensington, London.*
1883	Howie, Henry, *Harrington, Cumberland.*
1869	*Howson, R., *Exchange Place, Middlesbrough.*
1884	Hoyle, James Rossiter, *Norfolk Works, Sheffield.*
1878	Hoysradt, Jacob W., *Hudson, New York, U.S.A.*
1880	Huart, Baron F. d', *Longwy, Moselle, France.*
1885	Hudson, Wm. John, *Woodside Iron Works, Dudley.*
1880	Hudspeth, W., *Haltwhistle, Northumberland.*
1882	Huggett, J. A., *Plasket House, Grand Parade, Eastbourne.*
1877	Hughes, Arthur D., *care of* F. Taylor, 35 *Queen Victoria Street, London, E.C.*
1878	Hughes, John, *care of* F. Taylor, 35 *Queen Victoria Street, London, E.C.*
1888	Hughes, John James, 35 *Queen Victoria Street, London, E.C.*
1882	Hughes, Wm., 19 *Lionel Street, Birmingham.*
1887	Hulse, J. Whitworth, *Ordsal Works, Salford, Manchester.*
1882	Hulse, Wm. W., *Ordsal Tool Works, Salford, Manchester.*
1872	Humphreys, A. W., 45 *William Street, New York, U.S.A.*
1888	Hunt, Alfred E., 95 *Fifth Avenue, Pittsburgh, U.S.A.*

Elected Member

1889 Hunt, Charles,
Windsor Street, Birmingham.

1881 Huntington, Alfred Kirby,
King's College, London, W.C.

1876 Hurll, Jno.,
Woodneuk, Gartcosh, P.O., Glasgow.

1882 Hutchinson, Thomas C.,
Hilda House, Middlesbrough.

1889 Hutchinson, William,
Staffordshire Steel Company, Bilston.

1883 Hutton, A. W.,
Cyclops Iron Works, Walsall.

1876 Hutton, Robert,
Batts Foundry, Whitby.

1875 Ianson, James,
Fairfield House, Darlington.

1869 *Ianson, J. C.,
Glenholme, Saltburn-by-the-Sea.

1876 Ingham, William P.,
Middlesbrough.

1883 Ingram, C. W.,
Falconhyrst, Penarth, Cardiff.

1884 Jacks, William,
7 *Royal Bank Place, Glasgow.*

1881 Jackson, John,
Stubben Edge, Chesterfield.

1873 Jackson, W. F.,
Herndale House, Litton, viâ *Stockport.*

1881 Jacobi, Hugo,
Gutehoffnungshütte, Westphalia, Germany.

1869 *Jaffrey, G. W.,
Westland Terrace, 17 *Robertson Street, Greenock.*

1885 Jambille, Louis,
Maubeuge, France.

1889 James, Charles Henry,
8 *Courtland Terrace, Merthyr Tydfil.*

1889 James, Enoch,
Rhymney Iron Works, Rhymney, Monmouthshire.

1873 James, Phineas,
Abercarn Estate Office, Abercarn, Newport, Mon.

1884 James, J. W. Hy.,
2 *Victoria Mansions, Westminster, S.W.*

1883 Jamme, G.,
Dayton, Tennessee, U.S.A.

Elected Member

1884 Jameson, John,
Akenside Hill, Newcastle-on-Tyne.

1889 Jamieson, James Fleming Fyfe,
9 *Queen's Gate, London, S.W.*

1889 Jaques, Wm. Hy.,
Bethlehem Iron Company, Bethlehem, Pa, U.S.A.

1877 Jeans, J. S.,
Victoria Mansions, Victoria Street, S.W.

1879 Jefferies, J. R.,
Ipswich.

1888 Jeffreys, Edward Homer,
Hawkshill, Chapel Allerton, Leeds.

1876 Jenkins, A. T.,
Masbro' Boiler Works, Rotherham.

1872 Jenkins, James G.,
33 *Renfield Street, Glasgow.*

1869 *Jenkins, Sir J. J.,
The Grange, Swansea.

1869 *Jenkins, William,
Consett Iron Works, Consett, County Durham.

1874 Jenkins, William,
Dowlais Iron Works, Dowlais.

1885 Jenks, Isaac James,
Cleveland Iron Works, Wolverhampton.

1887 Jenks, Walter,
Minerva Works, Horseley Fields, Wolverhampton.

1882 Jennings, Charles,
East Parade, Consett, County Durham.

1875 Jennings, James,
3 *Ilminster Gardens, Lavender Hill, Clapham Junction, S*

1871 Johnson, Richard S.,
Sherburn Hall, Durham.

1871 Johnson, Thewlis,
Bradford Iron Works, Manchester.

1873 Johnson, Walter,
Exchange Buildings, Middlesbrough.

1875 Johnson, W. H.,
26 *Lever Street, Manchester.*

1880 Johnston, James,
Disley, Cheshire.

1881 Jonas, Joseph,
Continental Steel Works, Sheffield.

1882 Jones, Alfred W.,
Dashwood House, New Broad Street, E.C.

1870 Jones, Benjamin,
Dowlais Iron Works, Dowlais.

1886 Jones, Daniel Robert,
Dowlais Iron Works, Dowlais, Glamorganshire.

Elected Member	
1881	Jones, Edwin, *141 Cannon Street, London, E.C.*
1869	*Jones, Edwin F., *Normanby Iron Works, Middlesbrough.*
1878	Jones, Edwin While, *Cleveland Steel Works, South Bank, Middlesbrough.*
1874	Jones, Ephraim A., *Ayrton Rolling Mills, Middlesbrough.*
1884	Jones, James Cecil, *Rhymney Iron Works, South Wales.*
1870	Jones, John, *Dowlais Iron Works, Dowlais.*
1881	Jones, Joseph, *Corrugated Iron Works, Wolverhampton.*
1881	Jones, Wm. E., *141 Cannon Street, London, E.C.*
1889	Jopling, Thomas, *Otis Iron and Steel Coy., Cleveland, Ohio, U.S.A.*
1889	Jordan, Albert Edward, *Birchfield Lodge, Perry Barr, Birmingham.*
1889	Jordan, Andrew Jackson, 6, 8, 10 *Baker's Hill, Sheffield.*
1874	Jordan, Sampson, 5 *Rue Viètte, Quartier Monceaux, Paris.*
1875	Jordan, Thomas, *Dunkirk Iron Works, West Bromwich.*
1878	Jouraffsky, Demetrius, *St. Petersburg, Russia.*
1889	Jowitt, Charles Albert Renny, *Scotia Works, Sheffield.*
1882	Jowitt, Thomas W., *Scotia Steel Works, Sheffield.*
1879	Justice, P. M., 54 *Chancery Lane, London, W.C.*
1888	Kearsley, George, *British Iron and Implement Works, Ripon.*
1888	Keay, Ernest Charles, *Corporation Street, Birmingham.*
1885	Keen, Arthur, *Beechfield, Ampton Road, Edgbaston, Birmingham.*
1888	Keighley, George, *Bankhouse Iron Works, Burnley.*
1874	Kellett, William, 24 *King Street, Wigan.*

Elected Member	
1886	Kendall, J. Dixon, *Roper Street, Whitehaven.*
1884	Kennard, H. J., 20 *Hyde Park Terrace, London, W.*
1883	Kennedy, Professor A., F.R.S., *University College, London, W.C.*
1888	Kennedy, Myles, *Hill Fort, Ulverston.*
1881	Kenrick, Geo. H., *Whelstone, Somerset Road, Edgbaston, Birmingham.*
1883	Kerpely, A. Ritter von, *Buda Pesth, Hungary.*
1886	Kerr, Andrew, *Ardeer, N.B.*
1884	Kidner, John, *Islip House, Thrapston.*
1884	King, John William, *Sheffield Steel and Iron Works, Sheffield.*
1869	*Kirk, Henry, *Workington.*
1874	Kirk, Peter, *Mossbay Iron Works, Workington.*
1869	*Kirkconel, John F., *Furnace House, Cleator Moor,* viâ *Carnforth, Cumberland*
1888	Kirkhouse, Edward Godwin, *Consett Iron Works, Blackhill.*
1883	Kitching, A. E., *Elm Field, Darlington.*
1881	Kitching, John, *Branksome Hall, Darlington.*
1889	Kitson, Albert Ernest, *Monkbridge Iron Works, Leeds.*
1885	Kitson, Fredk. James, *Monkbridge Iron Works, Leeds.*
1869	*Kitson, Sir James, Bart., *Monkbridge Iron Works, Leeds.*
1879	Koch, Charles, *St. Chamond, Loire, France.*
1878	Koch, W. E., *Spang Iron and Steel Co., Sharpsburg, Pa., U.S.A.*
1888	Koch, Francis, *Alexandrowsky Steel Works, St. Petersburg.*
1884	Koehler, Henry, *Bochum, Westphalia, Germany.*
1875	Kolokoltzoff, Rear-Admiral, *Oboukoff Steel Works, St. Petersburg, Russia.*
1889	Korb, Friddlin, 29 *Spring Hill Road, Sheffield.*

Elected Member	
1889	Korten, Rudolph, *Messrs. Bolckow, Vaughan, & Co., South Bank, R.S.O., Yorkshire.*
1883	Krautner, Adolf, *Vordernberg, Styria.*
1886	Kriete, Henry C., 17 *Metropolitan Block, Chicago, U.S.A.*
1880	Kupelwieser, Paul, *Witkowitz, Austria.*
1874	Laing, James, *Sunderland.*
1883	Lancaster, Jno., *Anfield House, Leamington.*
1874	Lancaster, Joshua, *Talladega Iron and Steel Company, Alabama, U.S.A.*
1872	Landale, Andrew, *Echo Bank, Inverkeithing.*
1881	Langdon, Wm., *Huelva, Spain.*
1877	Larsen, Jno. Daniel, 67 *Belvedere Road, Upper Norwood, London, S.E.*
1885	Latinis, Victor, *Directeur de la Société des forges d'Acoz, Acoz, France.*
1888	Lauder, George, *Edgar-Thomson Steel Works, Pittsburg, U.S.A.*
1876	Lawson, Arthur T., *Beech Grove House, Leeds.*
1869	*Laybourne, Richard, *Isca Foundry, Newport, Monmouthshire.*
1873	Ledger, Joseph, *Castellette, Keswick.*
1887	Ledingham, L. Napier, *Brightside Steel Works, Sheffield.*
1887	Lee, Arthur, *Bessemer Road, Attercliffe, Sheffield.*
1889	Lee, Henry, *Sedgley Park, Prestwich, Lancashire.*
1874	Lee, William, 139 *Cannon Street, London, E.C.*
1873	Lees, Eli, 102 *Lancaster Gate, London, W.*
1887	Lees, John Bayley, *Oaklands, Church Lane, Handsworth.*
1887	Lees, Samuel, *Beacon View, Hill Top, West Bromwich.*

Elected Member

1889 Lees, Samuel,
Parkbridge, Ashton-under-Lyne.

1879
…use, Knutsford.

1888 … A.,
…ck, Pittsburg, U.S.A.

1880 …
Joliet Steel Co., Chicago, Illinois, U.S.A.

1882 Lennard, J. Milner,

1881 Leo, L.,

1878
…s, Walsall.

1887

1870 …, M.P.,
…eet, London.

1870
… Chambers, White Lion Court, Cornhill, E.C.

1869
Abercanaid, near Merthyr Tydfil.

1881
…andwell, Handsworth, Birmingham.

1882
…hambers, Westminster, S.W.

1871 …
…berdare.

1886
Whitehaven.

1889
…for Railways), Carlisle.

1888
…n.

1874 …n,
…ienna.

188…
…near Carnforth.

1881 Lindsay, Th…,
… Poultry, London, E.C.

1883
… Works, Melton Mowbray.

1882
… Street, E.C.

1881
… Brothers, Oldham.

…
Broad Street Avenue, Blomfield Street, E.C.

Works, Stoke-on-Trent.

esbury.

rook, Birmingham.

Road, Birmingham.

esbury.

ednesbury.

e Works, Lydney, Gloucestershire.

Road, Smethwick.

Tabley, near Knutsford.

et, E.C.
Looker,
E.C.

London, Brighton, and South Coast Rail-
Bridge, S.E.

Germany.

e Pasco Gold Field Coy., near Barberton,

ney Hill, London, E.C.

ildings, High Holborn, W.C.

Oberhausen, Westphalia.

ny.

ny.

Elected Member

1884 Lyon, Alfred C.,
Southbank, Compton, Wolverhampton.

1888 Lysaght, Wm. Royse,
Swan Gardens Iron Works, Wolverhampton.

1884
rington.

1883 de,
par Poire Saint Hubert, Belgium.

1884
Tyne.

1880

1889

1883

1886
vinside, Glasgow.

1879
Plate Works, Gilfig, Llanelly.

1888
Glasgow.

1882 Maclean,
Glasgow.

1888 S.,
W Glasgow.

1886
Glasgow.

1873
Spain.

1881 Macnee, D.,
2 *Westminster Chambers, London, S.W.*

1879 Main, Robert,
Ardeer Iron Works, Stevenston, Ayrshire.

1888 C.B.,
Woolwich Arsenal, Woolwich.

1879 Malo, Alberto,
Guanjuato, Mexico.

1889
Pitsmoor, Sheffield.

1870
Bewdley.

1888
ron Works, near Doncaster.

1879
te, Rothe Erde, near Puy-la-Chapelle.

rleroi, Belgium.

Bolt and Nut Works, London Road, Manchester.

Office, Hawthorn House, Bath.

St. Helens Road, Swansea, Glamorganshire.

Works, Glasgow.

Works, Middlesbrough.

Leslie, & Co., St. Peter's Works, Newcastle-on-Tyne.

R. C.,

Newton, near Glasgow.

Iron Works, Pendleton, Manchester.

Steel Works, Middlesbrough.

M.,

Rue de Provence, Paris.

,

hite Lion Court, Cornhill, London, E.C.

near Wolverhampton.

. H.,

Isaf, Llansamlet, Swansea.

Street, New York, U.S.A.

Works, Manchester.

Works, near Leeds.

Elected Member

1886 Mathieson, Thomas A.,
East Campbell Street, Glasgow.

1885 Mathieu, Jean A.,
51 *Moffat Block, Detroit, Michigan, U.S.A.*

1888 Matthews, John,
R. & W. Hawthorn, Leslie & Co. (Limited), Newcastle-o Tyne.

1874 Maw,
36 *Bedford Street, Strand, London, W.C.*

1881
Plate Works, Llanelly.

1888
Iron Works, Pendleton, Manchester.

1887 Mayer, Ernest,
Paris.

1874
New York, U.S.A.

1869
Chambers, London, S.W.

1884
and Steel Works, Mossend, Glasgow.

1884
ehaven.

1886
Villa, Carlyle Road, Manor Park, Essex.

1883
rlingham, Surrey.

1883
Lincoln's Inn, London.

1871 S.,
t Street, Glasgow.

1889 M S.,
Pennsylvania, U.S.A.

1878 M'Creath, James,
95 *Bath Street, Glasgow.*

1888
Whitehaven.

1889 M'Murty, George Gibson,
and Steel Company, Pittsburg, U.S.A.

1874
Oak Iron Works, Tipton.

1880 Melling, Samuel,
Ince Forge Company, Wigan.

1886 Melling, Thomas,
Ince Forge, Wigan.

1874 Mellon, Henry,
Ireleth, Askam-in-Furness.

Elected Member	
1883	Melnhof, Baron F. Mayr von, *Operngasse, 4, Vienna, Austria.*
1878	Merritt, W. H., 34 *St. George Street, Toronto, Canada.*
1886	Miller, J. Ritchie, 2 *Somerset Place, Glasgow.*
1886	Miller, Thomas, *London Road Foundry, Edinburgh.*
1882	Miller, John F., *Vulcan Foundry, Coatbridge, N.B.*
1889	Millward, George Anthony, 41 *Church Hill, Wednesbury.*
1875	Milner, Walter, *Whitecross Wire Works, Warrington.*
1870	Mitchell, Charles, *Newcastle-on-Tyne.*
1873	Mitchinson, H. S., *Bowling Iron Works, Bradford, Yorkshire.*
1884	Molineaux, W., *Capponfield Iron Works, Bilston.*
1870	Monks, F., *Walton Old Hall, near Warrington.*
1873	Moon, Richard, Jun., *Penyvael, Llanymynech, near Oswestry.*
1881	Moore, Alfred, *Fitzroy Works, Euston Road, London, N.W.*
1876	Moore, Arthur C., *Ida Wharf, Black Horse Bridge, Deptford, S.E.*
1882	Moore, William, *Leeds Steel Works, Leeds.*
1875	Morel, Ernest, *Tilleul Rolling Mills, Maubeuge, France.*
1880	Morgan, C. H., *Worcester, Mass., U.S.A.*
1881	Morgan, James Henry, 124 *Narrow Street, Limehouse, London, E.*
1882	Morgan, Thomas R., *Alliance, Ohio, U.S.A.*
1888	Morgan, Septimus Vaughan, 42 *Cannon Street, London, E.C.*
1882	Morris, Claude John, *The Mount, Altrincham.*
1883	Morris, Wm. H., 400 *Chestnut Street, Philadelphia, U.S.A.*
1874	Morrison, Martin, *Middlesbrough.*
1873	Morton, E. H., *Glenbrook, Cearn's Road, Oxton, Cheshire.*

Elected Member	
1879	Morton, James, *8 Princes Square, Buchanan Street, Glasgow.*
1879	Morton, James, *Manor Park, Blairhill, Coatbridge, N.B.*
1889	Moses, Edmund Bamford, *Cwm Avon, Glamorganshire.*
1875	Mosley, Col. Paget, *27 St. James' Square, London, S.W.*
1882	Mottram, Richard, *Knott Mill Iron Works, Manchester.*
1886	Mudd, Thomas, *Hartlepool.*
1883	Muirhead, Wm., *Parkhead Forge, Glasgow.*
1871	Müller, Charles Emile, *Middlesbrough.*
1881	Müller, R. W. Maxwell, *Scarboro' and Whitby Railway, Scarborough.*
1889	Müller, Thomas Neil, *Messrs. Müller & Co., Exchange Buildings, Middlesbrough.*
1885	Murisier, Oscar, *Acieries d'Alexandrowsky, St. Petersburg.*
1871	Musgrave, Jno., *Globe Iron Works, Bolton.*
1871	Musgrave, Joseph, *Globe Iron Works, Bolton.*
1888	Myers, W. Beswick, *14 Victoria Street, London, S.W.*
1889	Naylor, John William, *Wellington Foundry, Leeds.*
1883	Naylor, W., *Penistone, near Sheffield.*
1888	Needham, John, *13 Cannon Street, Manchester.*
1869	*Neesham, George, *Middlesbrough.*
1875	Neilson, George, *Summerlee Iron Works, Coatbridge, N.B.*
1882	Neilson, Hugh, Jun., *Clyde Bridge Steel Works, Cambuslang, N.B.*
1874	Neilson, James, *Mossend Works, Holytown Station, N.B.*
1869	*Neilson, John, *Summerlee, Coatbridge, N.B.*

Elected Member	
1882	Neilson, John A., *Summerlee Iron Works, Coatbridge, N.B.*
1880	Neilson, Walter, Jun., *Conservative Club, Glasgow.*
1881	Neilson, Walter, Jun., *Woodfield, Finedon, Wellingborough.*
1888	Nettlefold, John Sutton, *Castle Works, Tydu, Newport, Monmouthshire.*
1887	Newbigging, Thomas, *Manchester.*
1888	Nicholls, Thomas, *Cockin Villa, Barrow-in-Furness.*
1888	Nicholson, Henry, 37 *Stockton Street, Moss Side, Manchester.*
1889	Nicholson, James Percival *Bowling Iron Works, Bradford, Yorks.*
1885	Noble, James, *Grosvenor Terrace, Linthorpe Road, Middlesbrough.*
1877	Norbury, William Edward, *Knott Mill Iron Works, Manchester.*
1873	Nordenfelt, Thorsten, 53 *Parliament Street, London, S.W.*
1869	*Norris, W. G., *Coalbrookdale, Salop.*
1880	Nursey, Perry F., 161 *Fleet Street, London, E.C.*
1889	Oakes, Gerard R. *Riddings, Alfreton.*
1869	*Oakes, Thomas H., *Alfreton Works, Alfreton, Derbyshire.*
1880	Ogden, Samuel, *Werneth House, Oldham.*
1883	Ogilvie, A. G., 4 *Great George Street, London, S.W.*
1883	Ogle, Percy Jno., 4 *Bishopsgate Street Within, London, E.C.*
1875	Ogle, Richard, 4 *St. Ann's Square, Manchester.*
1884	Oliver, D. B., 114 *First Avenue, Pittsburg, Pennsylvania, U.S.A.*
1884	Oliver, H. W., Jun., 114 *First Avenue, Pittsburg, Pennsylvania, U.S.A.*
1881	Onions, Edward, *Ardsley House, East Ardsley, near Wakefield.*
1887	Ordoñez, Escandon Salvador y, *c/o M. Cardeñosa,* 20 *Mark Lane, London.*

ngston, near Glasgow.

'orks, Sheffield.

npany, Cleveland, Ohio, U.S.A.

nany.

els.

norganshire.

lington, Salop.

asgow.

t Bromwich.

ill, London, E.C.

rishnugsher, Bengal, India.

P.,

castle-on-Tyne.

on-Tees.

asgow.

'orks, Barrow-in-Furness.

nhill, London, E.C.

Bromwich.

outh Street, Birmingham.

d Anchor Works, Tipton.

kinfield, near Manchester.

Elected Member

1881 Parratt, W.,
58 *Lyndhurst Road, Peckham, London, S.E.*
1869 *Parry, John,
Ebbw Vale Iron Works, Newport, Monmouthshire.
1874 Parsons, P. M.,
House, Blackheath, Kent.
1888
Directeur du Laminoir des Acieries, Dudelange, Grand duchi de Luxembourg.
1879
many.
1878
Halifax.
1882
Iron Works, Hadley, Wellington, Salop.
1887

1884 Paterson, John,
106 *Hawthorne Terrace, Workington.*
1886 Patterson, Anthony,

1869
75 *Sic ... ewcastle-on-Tyne.*
1874 Pattison, John,

1887
m.
1881
Works, Newton, Glasgow.
1876 Wm.,

1878 Nash,
Tunstall, Staffordshire.
1889 George, Bart.,
yss Bay, N.B.
1885
Manchester.
1877 Pears,
Witton-le-Wear, Darlington.
1883
near Birmingham.
1875
Iron Works, West Bromwich.
1873 H.,
Company, Wigan.
1883 Pearson, W. G.,
97 *Cannon Street, London, E.C.*

Elected Member	
1884	Pease, Arthur, *Darlington.*
1888	Pease, John Francis, *Pierremont, Darlington.*
1887	Pease, Joseph Albert, *Darlington.*
1882	Pease, Henry Fell, M.P., *Darlington.*
1869	*Pease, Sir Joseph W., Bart., M.P., *Hutton Hall, Guisbro', Yorks.*
1875	Pechin, E. C., 303 *Prospect Street, Cleveland, Ohio, U.S.A.*
1883	Peech, W. H., *Phœnix Bessemer Steel Works, Ickles, near Sheffield.*
1885	Peile, Wm., *Cartgate, Hensingham, Whitehaven.*
1880	Pendred, V., 163 *Strand, London, W.C.*
1881	Pepper, Joseph E., *Clarence Iron Works, Leeds.*
1884	Percy, Thomas McLeod, *Wigan Coal and Iron Works, Wigan.*
1884	Perks, George Henry, *Elter-Water Hall, Ambleside.*
1879	Pernot, Chas., *St. Chamond, Loire, France.*
1889	Peters, Theodor, 14 *Wichmannstrasse, Berlin.*
1885	Petherick, John, *Consett Iron Works, Blackhill, Co. Durham.*
1873	Petin, Jean J. Hippolyte, *Rue Mont Grand* 24, *Marseilles, France.*
1874	Peto, Samuel Arthur, *Plumbago Crucible Works, Battersea, London, S.W.*
1883	Phipps, Hy., Jun., *Pittsburg, Pa., U.S.A.*
1874	Piedbœuf, Gustave, *Aix-la-Chapelle.*
1884	Pierce, J. J., *Sharpsville, Pennsylvania, U.S.A.*
1886	Pilkington, Herbert, *Barnfield House, Tipton.*
1887	Ping, Francis, *The Avenue, Linthorpe, Middlesbrough.*
1876	Pink, Richard, 6 *Sedars Strasse, Hanover, Germany.*
1882	Pirie, Lewis J., *King William's* Town, Cape Colony, South Africa.

Elected Member	
1883	Platt, Jas. E., *Messrs. Platt Brothers, Oldham.*
1882	Platt, James, *Atlas Iron Works, Gloucester.*
1873	Platt, Samuel R., *Werneth Park, Oldham.*
1889	Pochin, Henry D., *Bodnant Hall, Eghoysbach, R.S.O., Denbighshire.*
1881	Poensgen, Carl, *Düsseldorf, Germany.*
1881	Poensgen, Rudolph, *Düsseldorf, Germany.*
1881	Ponthière, Honoré, *Louvain University, Belgium.*
1886	Polson, John, *Castle Levan, Greenock, N.B.*
1887	Pope, Samuel, *Tinsley House, Tinsley, Sheffield.*
1885	Potter, E. C., *South Chicago Works, Chicago, U.S.A.*
1872	Potts, John Thorpe, 1001 *Chestnut Street, Philadelphia, U.S.A.*
1879	Pourcel, Alexandre, *Saltburn-by-the-Sea.*
1883	Powell, W. H., *Ebbw Vale, Monmouthshire.*
1889	Preston, Fredk. Walter, *Kettering Iron and Coal Company, Kettering.*
1878	Price, John, 6 *Osborne Villas, Jesmond, Newcastle-on-Tyne.*
1874	Price, Joseph, Jun., *Brunswick Foundry, Liverpool.*
1883	Prochaska, J., *Graz Steel Works, Graz, Austria.*
1869	*Putnam, William, *Darlington Forge, Darlington.*
1884	Putnam, Thomas, *Darlington Forge, Darlington.*
1881	Pye-Smith, Arnold, 32 *Queen Victoria Street, E.C.*
1885	Radcliffe, Francis, 233 *Burridge Road, Plumstead, London, S.E.*
1879	Radford, R. H., 15 *St. James's Row, Sheffield.*

Elected Member	
1874	Ramage, John, *Beckenham, Kent.*
1869	*Ramsbottom, John, *Fernhill, Alderly Edge, Cheshire.*
1869	*Ramsden, Sir James, *Barrow-in-Furness.*
1869	*Ramsden, W. G., 13 *Tower Chambers, Liverpool.*
1879	Ransome, Allen, *Stanley Works, King's Road, Chelsea, S.W.*
1887	Ransome, Frederick, *Rushmere Lodge, Norwood Road, London, S.E.*
1889	Ransome, Robert James, *Water-side Works, Ipswich.*
1874	Rapier, Richard C., 5 *Westminster Chambers, London, S.W.*
1888	Rapley, Frederick Harvey, *Dashwood House, London, E.C.*
1869	*Ratliffe, George, 81 *Cannon Street Buildings, Cannon Street, E.C.*
1874	Ray, Edmund, *Lindal Moor Mines, Ulverston.*
1871	Reay, Thomas M., *Spennymoor, County Durham.*
1882	Reay, Thomas P., *Airedale Foundry, Leeds.*
1870	Reed, Sir E. J., M.P., *Broadway Chambers, Westminster, S.W.*
1880	Reichwald, A., *Newcastle-on-Tyne.*
1889	Reimers, E., 19 *Schonsbeckerstrasse, Magdeburg, Buckau, Germany.*
1880	Remaury, M., 56 *bis, rue de Chateaundun, Paris.*
1883	Rendel, W. Stuart, 8 *Great George Street, Westminster.*
1878	Renton, Benjamin Mann, *Savile Street, Sheffield.*
1886	Resimont, Armand, *Valenciennes, Nord, France.*
1885	Reynolds, George B., 23 *Longridge Road, Earl's Court, S.W.*
1881	Reynolds, Thos., 99 *Cromwell Road, South Kensington, S.W.*
1887	Rhodes, George W., *The Cottage, Victoria Park, Manchester.*
1889	Richards, David, *Hillside, Ammanford, Carmarthenshire.*

n,
Blaina Works, Blaina, R.S.O., Monmouthshire.
ndsor,
House, Lowmoor.

Works, Sheffield.

House, Shirley Road, Acock's Green, Birmingham.

Street, Dowlais.

Terrace, London, W.
1869

1869 P.,

1872
Chesterfield.
1869
Works, Oldham.
1881
Strasse, 60, Berlin, Germany.
1875 ,
Newby Bridge, Ulverston.
1889 Barrett,
Iron Company, Springfield, Illinois, U.S.A.
1869 .,
mmerhill Grove, Newcastle-on-Tyne.
1877 D.,
Redcar.
1883
ange, Guisbrough, Yorkshire.
1873
Finsbury Square, London, E.C.
1874 s,
hange Square, Glasgow.
1873
Works, Bradford.
1882
,
ear Neath, S. Wales.
1881 V.,
ustin Friars, London, E.C.
1881 W. Chandler, F.R.S.,
London, E.
1888
West Bromwich.
1885 W.,
South Russell Street, Grahamston, Falkirk.

enry B.,
orwen, South Wales.

Hall, Leek, Staffordshire.
ed.,
Sheffield.

Hall, Bishop Auckland.

Works, Sheffield.

Works, Rochdale.

House, Redcar.

,
n Street, Glasgow.

nue Rogier, Liége, Belgium.

dser Road, Upper Tooting, S.W.
W.,
Steel Company, Alliance, Ohio, U.S.A.
,
Meurthe, France.

Works, Llanelly.

Hall, Durham.
R., Colonel,
ia Nazionale, Rome, Italy.
nes,
Wire Mills, Erdington, Birmingham.

5, Wien, Austria.
Henry, M.P., F.R.S.,
Gardens, London, S.W.

.,
m Iron Ore Company, Lincoln.
d,
and L. Railway, Marple, Cheshire.

Furnaces, Tividale, Tipton.

,
Terrace, Acton Vale, W.

Crescent, Maida Vale, London, W
illiam,
y, near Southampton.

Elected Member	
1888	Ruscoe, John, *Hyde, near Manchester.*
1877	Russell, Emil, *Die Direction der Disconts Gesellschaft, Berlin.*
1882	Russell, John, 8 *Victoria Chambers, Westminster.*
1883	Russell, W., *Pather Iron Works, Wishaw, N.B.*
1885	Russell, Robert, *Coltness Iron Works, Newmains, N.B.*
1886	Russell, George, *Summerlee Iron Works, Coatbridge, N.B.*
1882	Sach, Augustus T., *Beech House, Bowdon, near Altringham.*
1877	Sacré, Alfred Louis, 60 *Queen Victoria Street, London, E.C.*
1887	St. Oswald, Lord, *Nostell Priory, Wakefield.*
1880	Salmon, F. B., *Birkenhead Forge, Birkenhead.*
1880	Salter, M., *Workington.*
1889	Sampson, Richard H., *Pontardulais, South Wales.*
1886	Samuel, James, *Glengarnock, N.B.*
1869	*Samuelson, Sir B., Bart., M.P., 56 *Prince's Gate, South Kensington, S.W.*
1885	Samuelson, Francis A. E., *Sockburn Hall, Darlington.*
1887	Sandahl, Carl J., *Trimsaran, S. Wales.*
1877	Sartoris, Herbert, *Kettering Furnaces, Kettering.*
1887	Saunders, James, 86 *Darlington Street, Wolverhampton.*
1889	Sauvée, Albert, 22 *Parliament Street, London, S.W.*
1875	Sawrey, John S., *Fell Side, Pennington, near Ulverston.*
1872	Scattergood, J., *Stour Valley Works, Spon Lane, Birmingham.*
1883	Schlegtendal, F., *Duisburg, Germany.*

Elected Member	
1882	Schlink, Joseph, *Friedrich-Wilhelmshütte, Mulheim-on-the-Ruhr, Germany.*
1876	Schneider, Henry, *Creusôt, France.*
1875	Schofield, C. J., *Clayton, near Manchester.*
1881	Schott, Robert, *Dannemora Steel Works, Sheffield.*
1888	Schrodter, E., *Secretary, German Ironmasters' Association, Dusseldorf, Germany.*
1884	Schroller, Wm. C. P. H., 20 *Mount Street, Manchester.*
1885	Schultz, George, *Botolph House, Eastcheap, E.C.*
1884	Schulz, G., 8 *Friedrichstrassse, Bochum, Westphalia.*
1881	Scott, Ernest, *Close Works, Newcastle-on-Tyne.*
1878	Scott, Fife J., *Newcastle-on-Tyne.*
1882	Scott, Ralph G., *Monkbridge Iron Works, Leeds.*
1878	Scott, William Henry, *Newcastle-on-Tyne.*
1888	Scoular, George, *Hensingham, Whitehaven.*
1882	Seaman, Fred., *Oak Mount, Adelaide Road, Brincliffe, Sheffield.*
1880	Seddon, R. B., *Wigan.*
1883	Seebeck, Leopold, *Crosby Buildings, Crosby Square, E.C.*
1877	Seebohm, Henry, 22 *Courtfield Gardens, South Kensington.*
1889	Seehoff, Robert, *Witten, Westphalia, Germany.*
1874	Sellers, William, 1600 *Hamilton Street, Philadelphia, U.S.A.*
1881	Senior, George, *Pond's Forge, Sheffield.*
1888	Sennett, Richard, *Messrs. Maudslay, Sons, & Field, Ld., Engineers, Lambeth.*
1879	Sepulchre, A., *Aulnoye-lez-Berlaiemont, France.*
1878	Sepulchre, François, *Vezin, Belgium.*

Elected Member	
1880	Shakell, W. H., *Weardale Iron and Coal Co., Limited, George Yard, Upper Thames Street, London, E.C.*
1886	Share, Geo. W., 72 *King William Street, London, E.C.*
1869	*Sharp, Henry, *Bolton Iron and Steel Works, Bolton.*
1883	Sharp, J., 5 *St. Bernard's Crescent, Edinburgh.*
1872	Shaw, William, Sen., *The Cast Steel Foundry, Middlesbrough.*
1888	Sheldon, John George, *Seaton Carew.*
1869	*Shield, Clifton, *Reform Club, Pall Mall, London.*
1878	Shinn, William P., *New England Railway Co.*, 36 *Wall Street, New York, U.S.A.*
1883	Shipman, John W., *Attercliffe Steel Wire Mills, Sheffield.*
1889	Siddell, George, *Roewood, Crabtree, Pitsmoor, Sheffield.*
1878	Siemens, Alexander, 12 *Queen Anne's Gate, Westminster, London, S.W.*
1884	Siemens, Frederick, 12 *Queen Anne's Gate, Westminster, London, S.W.*
1876	Siltzer, John, 4 *Cromwell Houses, South Kensington, London, S.W.*
1883	Simmons, Charles, *Darlington Steel Works, Darlington.*
1874	Simon, Henry, 20 *Mount Street, Manchester.*
1883	Simons, D., *Moss Bay Steel Works, Workington.*
1880	Simpson, F. F., *Park Lane Iron Works, Oldbury.*
1877	Simpson, J. B., *Hedgefield House, Blaydon-on-Tyne.*
1888	Simpson, Joseph, *Moss Close, Walsall.*
1874	Simpson, J. S., *Harrington Iron Works, Harrington, Cumberland.*
1876	Simpson, William W., *Oswaldtwistle Collieries, near Accrington.*
1884	Simpson, Henry Charles, *Horsehay, near Wellington, Shropshire.*
1885	Simpson, Matthew H., *Queen Street, Lancaster.*

Elected Member	
1886	Simpson, Robert, *Harrington, Cumberland.*
1889	Slater, James, *Bescot Hill, Walsall.*
1874	Smith, Charles, *Steel Works, Barrow-in-Furness.*
1881	Smith, C. Weston, *Langland Hall, Mumbles, South Wales.*
1869	*Smith, E. Fisher, 34 *Avenue Road, Regent's Park, London, N.W.*
1882	Smith, Fred., *Caledonia Works, Halifax, Yorkshire.*
1882	Smith, G. Jackson, *Clyde Street Works, Sheffield.*
1889	Smith, Henry John, *Newmains, N.B.*
1880	Smith, Jno. Jos., *Southwood House, Eltham, Kent.*
1869	*Smith, John Stores, *Sheepbridge Iron Works, Chesterfield.*
1882	Smith, Joseph H., *Summerhill, Kingswinford, near Dudley.*
1869	*Smith, Josiah T., *Rhine Hill, Stratford-on-Avon.*
1887	Smith, Richard, *Royal School of Mines, S. Kensington, London.*
1874	Smith, Robert, *Castle Hill, Sheffield.*
1889	Smith, Samuel, *Monway Steel Works, Wednesbury.*
1876	Smith, Thomas Taylor, *Greencroft Park, Durham.*
1885	Smith, Watson, *University College, Gower Street, W.*
1884	Smith, W. A., *Heyford Iron Works, near Weedon, Northampton.*
1877	Smith, W. Ford, *Gresley Iron Works, Manchester.*
1876	Smyth, Samuel Richard, 2 *Ducie Street, Clapham, S.W.*
1869	*Snelus, G. J., F.R.S., *West Cumberland Iron and Steel Works, Workington.*
1884	Soldenhoff, Richard de, 71 *St. Mary's Street, Cardiff.*
1884	Somers, Walter, *Hayword Forge, Birmingham.*
1884	Sorby, T. W., *Storthfield, Sheffield.*

Elected Member

1886 Sorby, Henry C., F.R.S.,
Broomfield, Sheffield.

1885 Sotomayor, Major F. Alvarez,
Ordnance Works, Trubia, Spain.

1872 Sparrow, Arthur,
Preese Manor, Shrewsbury.

1889 Sparrow, Henry,
Himley, Dudley.

1873 Sparrow, J. W.,
Beckminster, Wolverhampton.

1889 Spencer, Charles,
West Stockton-on-Tees Iron Works, Stockton.

1869 Spencer, John,
Phœnix Works, Coatbridge, N.B.

1888 Spencer, John,
Globe Tube Works, Wednesbury.

1884 Spencer, J. Cuthbert,
Walbottle Hall, Newcastle-on-Tyne.

1879 Spencer, J. W.,
Newburn Steel Works, Newcastle-on-Tyne.

1869 *Spencer, Thomas,
The Grove, Ryton, Blaydon-on-Tyne.

1880 Squire, Edw. L.,
Coalbrookdale Iron Works, Shropshire.

1888 Squire, Lionel R. Littler,
30 *St. John's Wood Park, London, N.W.*

1878 Stanger, William Harry,
Chemical Laboratory and Testing Works, Broadway, Westminster, S.W.

1881 Stanley, John W.,
The Laboratory, Tondu, Bridgend, Glamorganshire.

1873 Stead, J. E.,
5 *Zetland Road, Middlesbrough.*

1886 Steel, Henry, Jun.,
Phœnix Steel Works, Ickles, Sheffield.

1886 Steel, Wm.,
Phœnix Steel Works, Ickles, Sheffield.

1873 Steer, Edward,
Castle Works, Tydu, near Newport, Monmouthshire.

1885 Stephenson, Robert,
Stockton Malleable Iron Company, Stockton-on-Tees.

1877 Sterne, Louis,
2 *Victoria Mansions, Westminster, S.W.*

1880 Steven, Thos.,
Milton Iron Works, Glasgow.

1875 Stevens, Warwick Allan,
Darlington Works, Southwark Bridge Road, London.

Elected Member	
1869	*Stevenson, John, *Acklam Iron Works, Middlesbrough.*
1873	Stewart, Andrew, 41 *Oswald Street, Glasgow.*
1873	Stewart, James, 41 *Oswald Street, Glasgow.*
1883	Stewart, Peter, *Tharsis Sulphur and Copper Co., Glasgow.*
1874	Stileman, F. C., 23 *Great George Street, Westminster, S.W.*
1876	Stoddart, Charles John, *Parkgate Iron Works, Rotherham.*
1872	Stoker, F. W., *Easton & Anderson Co. (Ld.), Erith Iron Works, Erith, K*
1880	Storey, Sir Thomas, *Lancaster.*
1884	Storey, E., 1 *Rumford Place, Liverpool.*
1888	Storey, Thomas E., *Kidsgrove, Staffordshire.*
1887	Storey, Wm. John Patrickson, *Douglas House, Rhyl, N. Wales.*
1888	Storr, Frederick, 21 *The Groves, Chester.*
1886	Storr, Walter W., 11 *Temple Street, Swansea, Glamorganshire, South Wal*
1885	Straker, Herbert, *Thornaby Iron Works, Stockton-on-Tees.*
1879	Strang, J. H., *Lochburn Iron Works, Glasgow.*
1883	Strange, A. J., *West Cumberland Iron and Steel Works, Workington.*
1876	Strick, George Henry, *Amman Iron Works, Swansea.*
1880	Strick, Jno., *Bar Hill, Madeley, Staffordshire.*
1889	Stroudley, W., *Locomotive Engineer, Brighton.*
1883	Stuart, Professor J., M.P., *University, Cambridge.*
1881	Stubbs, Frederick, *Broomfield, Newbould Lane, Sheffield.*
1885	Sturrock, David, *Carntyne Iron Co., Glasgow.*
1872	Summers, James W., *Globe Iron Works, Staleybridge.*
1872	Sumner, William, *Brazenose Street, Manchester.*

Elected Member

1876 Sutcliffe, F. John Ramsbottom,
Low Moor Iron Works, Bradford, Yorks.

1872 Sutherland, The Duke of, K.G.,
Stafford House, St. James's, London.

1883 Sutherland, Wm.,
Poplar Avenue, Sandon Road, Birmingham.

1873 Swan, Edward W.,
Middlesbrough.

1873 Swan, Herbert A.,
Middlesbrough.

1874 Swan, Henry F.,
North Jesmond, Newcastle-on-Tyne.

1869 *Swan, John G.,
Cargo Fleet Iron Works, Middlesbrough.

1869 *Swindell, J. E.,
Cradley Iron Works, Stourbridge.

1881 Sykes, Robert,
Acres House, Stalybridge.

1879 Tait, James,
Raisby Hill Lime Works, Coxhoe, County Durham.

1869 Tate, John,
Workington Hematite Iron and Steel Co. (Ld.), Workington.

1875 Tatham, Thomas,
102 *Corporation Street, Manchester.*

1880 Taylor, James,
Shirecliffe Cottage, Shirecliffe Lane, Sheffield.

1888 Taylor, Joseph Samuel,
Derwent Foundry, Birmingham.

1876 Taylor, T. A. O.,
Clarence Iron Works, Leeds.

1887 Taylor, James,
Park House, Queen's Road, Oldham.

1887 Tench, Wm. R.,
Hamilton Iron Works, Garston, near Liverpool.

1879 Tennant, Sir Charles, Bart.,
St. Vincent Street, Glasgow.

1885 Thackray, Wm., Jun.,
7 *The Avenue, Sunderland.*

1875 Thielen, Alex.,
Phœnix Iron Works, Ruhrort, Rhenish Prussia.

1888 Thomas, James Lewis,
Bryn Awel, Aberdare.

1889 Thomas, John Glyn,
Llangennech, South Wales.

Elected Member	
1888	Thomas, Richard, *Birchill's Iron Works, near Walsall.*
1881	Thomas, R. B., *Lydbrook, Gloucestershire.*
1878	Thomas, William, *Bryn Awel, Aberdare.*
1888	Thomas, William, *Portway Works, Wednesbury.*
1878	Thomas, William Henry, 15 *Parliament Street, S.W.*
1882	Thomlinson, Wm., *Seaton Carew, near West Hartlepool.*
1882	Thompson, Sir Henry M. Meysey, Bart., *Kirby Hall, York.*
1882	Thompson, James, *Singleton Park, Kendal.*
1889	Thompson, Philip, *Clarence Iron Works, Middlesbrough.*
1883	Thompson, S. Jno., *Muchall Grove, Wolverhampton.*
1886	Thompson, Robert, *Fulwell West House, Sunderland.*
1879	Thomson, Charles, *Calder Iron Works, Coatbridge, N.B.*
1873	Thomson, Graham H., 129 *Trongate, Glasgow.*
1882	Thomson, James R., *Clyde Bank, Dumbartonshire.*
1869	*Thomson, J. M., *Calder Iron Works, Glasgow.*
1878	Thomson, John, *Eston Mines, near Middlesbro'-on-Tees.*
1881	Thwaites, Edward H., *Vulcan Iron Works, Bradford, Yorks.*
1871	Tinn, Joseph, *Bristol Bank Buildings, Bristol.*
1874	Todd, Hadden W., *St. Helens, Lancashire.*
1884	Tolmie, A. D., 166 *Buchanan Street, Glasgow.*
1882	Tomkys, Joseph, *Carr House Iron Works, West Hartlepool.*
1889	Tompkin, John Benjamin, *Newhall Steel Works, Sheffield.*
1885	Tonks, Edwin, *Holly Cottage, West Smethwick.*
1870	Tosh, E. G., *North* Lonsdale Iron and Steel Company, Ulverston.

9

Elected Member	
1870	Tosh, George, *North Lincolnshire Iron Works, Scunthorpe, Doncaster.*
1881	Tosh, R. George, *North Lincolnshire Iron Works, Scunthorpe, Doncaster.*
1883	Tozer, Wm., *Phœnix Bessemer Steel Works, Ickles, near Sheffield.*
1883	Trasenster, Paul, *Boulevard Frère-Orban, 4, Liége, Belgium.*
1889	Triponé, Emile, 35 *Rue de Rome, Paris.*
1881	Trubshaw, Ernest, *Western Tin Plate Works, Llanelly, South Wales.*
1880	Tucker, A. E., *Holly Street, Smethwick.*
1886	Turner, Thomas, *Corngreaves Iron Works, near Birmingham.*
1887	Turner, Thomas, *Mason Science College, Birmingham.*
1884	Turton, Geo., *Patent Buffer Steel and File Works, Sheffield.*
1884	Turton, John, *Vulcan Forge and Rolling Mills, Sheffield.*
1885	Tweedie, Jas. A., 12 *St. Andrew Square, Edinburgh.*
1889	Twynam, Thomas, 7 *Marlborough Terrace, Bedford Park, London, W.*
1889	Tylden-Wright, Charles, *The Priory, Dudley.*
1887	Tyzack, Wm. A., *Stella Works, Hereford Street, Sheffield.*
1879	Upton, Douglas, *Codnor Park, Alfreton.*
1874	Valentine, Charles J., *Marshside, Workington.*
1875	Valton, Ferdinand, 166 *Fauborg St. Honoré, Paris.*
1886	Varley, John, *Leeds Forge Co., Leeds.*
1883	Vapart, M., *Angleur, near Liége, Belgium.*
1873	Vaughan, Cedric, *Hodbarrow Mines, Millom, Cumberland.*
1885	Verdié, E., 75 *Rue de la Victories, Paris.*

Elected Member

1869 *Vickers, T. E.,
River Don Works, Sheffield.

1881 Felix,

1883

1869
Barrow-in-Furness.

1870
on-in-Furness.

1883
nd Axletree Company, Wednesbury.

1885
Sunderland.

1886
Hall, near Newport, Shropshire.

1869
t Works, Leeds.

1875
s, Wigan.

1874
Yorkshire.

1888

1888 ginn, Jun.,
Vorks, Sheffield.

1889 se,
mpany, Chicago, U.S.A.

1887 Wallis, James J.,
10 *St. Swithin's Lane, London, E.C.*

1869
70 *Bolton.*

1875 Walton,

1878
s, Middlesbrough.

1889 Pearson,
Street, Wishaw, N.B.

1869 Ward, George,
House, W

1869
Works,

1878 Ware, Charles William,
37 *Grosvenor Place, Newcastle-on-Tyne.*

Warren, Edwin Caleb,
120 *Queen Victoria Street, E.C.*

Elected Member

1888 Warrington, Henry James,
Berry Hill Farm, Stoke-on-Trent.

1889 Watt, John Landale Wilson,
3 *Alexandra Place, Dennistown, Glasgow.*

1876 Webb, F. W.,
Chester Place, Crewe.

1873 Webb, Henry,
Irwell Forge, Bury.

1872 Webb, Henry A.,
Church Street Chambers, Stourbridge.

1873 Wedekind, Hermann,
158 *Fenchurch Street, London, E.C.*

1878 Weeks, Joseph D.,
Pittsburg, Pa., U.S.A.

1872 Weir, William,
Gartsherrie Iron Works, Coatbridge, N.B.

1878 Wellman, Samuel J.,
1080 *Willson Avenue, Cleveland, Ohio, U.S.A.*

1882 Wells, Charles,
Moxley Steel and Iron Works, near Wednesbury.

1872 Wendel, Henri de,
Hayange, Lorraine, Germany.

1872 Wendel, Robert de,
Hayange, Lorraine, Germany.

1889 Western, Chas. Robert,
Broadway Chambers, London, S.W.

1878 Westmacott, Percy,
Benwell Hill, Newcastle-on-Tyne.

1871 Wheelock, Jerome,
Worcester, Mass., U.S.A.

1879 While, Adolph S.,
32 *Regent Street, New Swindon.*

1883 While, Charles,
Curwen Street, Workington.

1879 While, J. M.,
Darlington Steel Works, Darlington.

1883 Whipham, A. H.,
Queen's Square, Middlesbrough.

1883 White, Hy.,
Derwent House, Gold Tops, Newport, Mon.

1887 White, Henry,
Bridge Street, Worksop.

1885 White, John Henry,
Derwent Works, Workington.

1889 White, Maunsel,
Bethlehem Iron Company, Bethlehem, Pa., U.S.A.

1873 Whitehead, John,
Penwortham Priory, Preston, Lancashire.

Elected Member

1886 Whitelaw, Thomas,
Street, Glasgow.
1885 J.,
Ulverston.
1881 ,
'ewport, Mon.
1870
Iron Works, Leeds.
1873
'orks, Leeds.
1888
Chorley, Lancashire.
1869
Iron Works, Stockton-on-Tees.
1876 . Buckton & Co.,
se Foundry, Leeds.
1889
Works, Mexbrough, Yorks.
1881
Yorkshire.
1888 Wilkinson, George W.,
Monmouthshire.
1882
'ills, Tipton.
1885 W.,
1888
99 *Burngreave Road, Sheffield.*
1884 Willans, B.,
1878 William,
Buildings, 28 Deansgate, Manchester.
1878
vence, Paris.
1875
and Tinplate Co., Pontypool, Monmouthshire.
1883
'ice, Manchester.
1880
Works,
1880
House, Pontypool, Monmouthshire.
1889
The Fields, Newport, Monmouthshire.
1880 Williams, John,
Rogerston House, Tydu, Newport, Monmouthshire.
1872 Williams, Nicholas,
Hodbarrow Mines, Millom, Cumberland.

Elected Member

1888 Williams, Penry,
on Works, Middlesbrough.

1889

Works, Wrexham.

1869

Works, Wednesbury.

1872

Street, London, S.W.

1874

Works, Wishaw, N.B.

1869

Iron Works, Tipton.

1877

Birmingham.

1882

Forest Steel and Tinplate Works, Swansea.

1880 R. H.,

1873

1877

1885

N.B.

1870

1869

1875 Wilson, Alfred,
Engineer, Stafford.

1873

House, Murrayfield, Edinburgh.

1889

, Bala, North Wales.

1869 P.,

1869 *

1886

1884

Lane, London, W.C.

1879 Wise, . Lloyd,
46 *Lincoln's Inn Fields, W.C.*

1884

Pittsburg, U.S.A.

1873 Withy, Edward,
Avon Villa, Parnell, Auckland, New Zealand.

Elected Member	
1871	Würzburger, Philip, *Creuznach, Rhenish Prussia.*
1878	Wynne, Francis George, 5 *Westminster Chambers, London, S.W.*
1883	Ybarra, Don José A. de, *Ronda de Recoletos*, 3, *Madrid, Spain.*
1883	Ybarra, Tomas de Z., *Bilbao, Spain.*
1884	Young, Edmund B., *Bolckow, Vaughan, & Co., Middlesbrough.*
1880	Young, James, *Lowmoor Iron Works, near Bradford.*
1886	Young, Robert, *Victoria Street, London, S.W.*
1889	Zabalburn, Ramon de Jaurequi y, *Bilbao, Spain.*
1882	Zeitz, Th., *St. Peter's Close, Sheffield.*
1881	Ziane, Jules, 2 *Rue Hotel des Monnaies, St. Giles, Brussels.*

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